NASA Technical Memorandum 102144

Ice/Frost/Debris Assessment For Space Shuttle Mission STS-27R

February 1989

(NASA-TM-102144) ICE/FROST/DEBRIS
ASSESSMENT FOR SPACE SHUTTLE MISSION
STS-27R, DECEMBER 2, 1988 (NASA) 200 p
CSCL 22B
N89-19326
Unclas
G3/16 0190186

National Aeronautics and
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ICE/FROST/DEBRIS ASSESSMENT
FOR
SPACE SHUTTLE MISSION
STS-27R
DECEMBER 2, 1988

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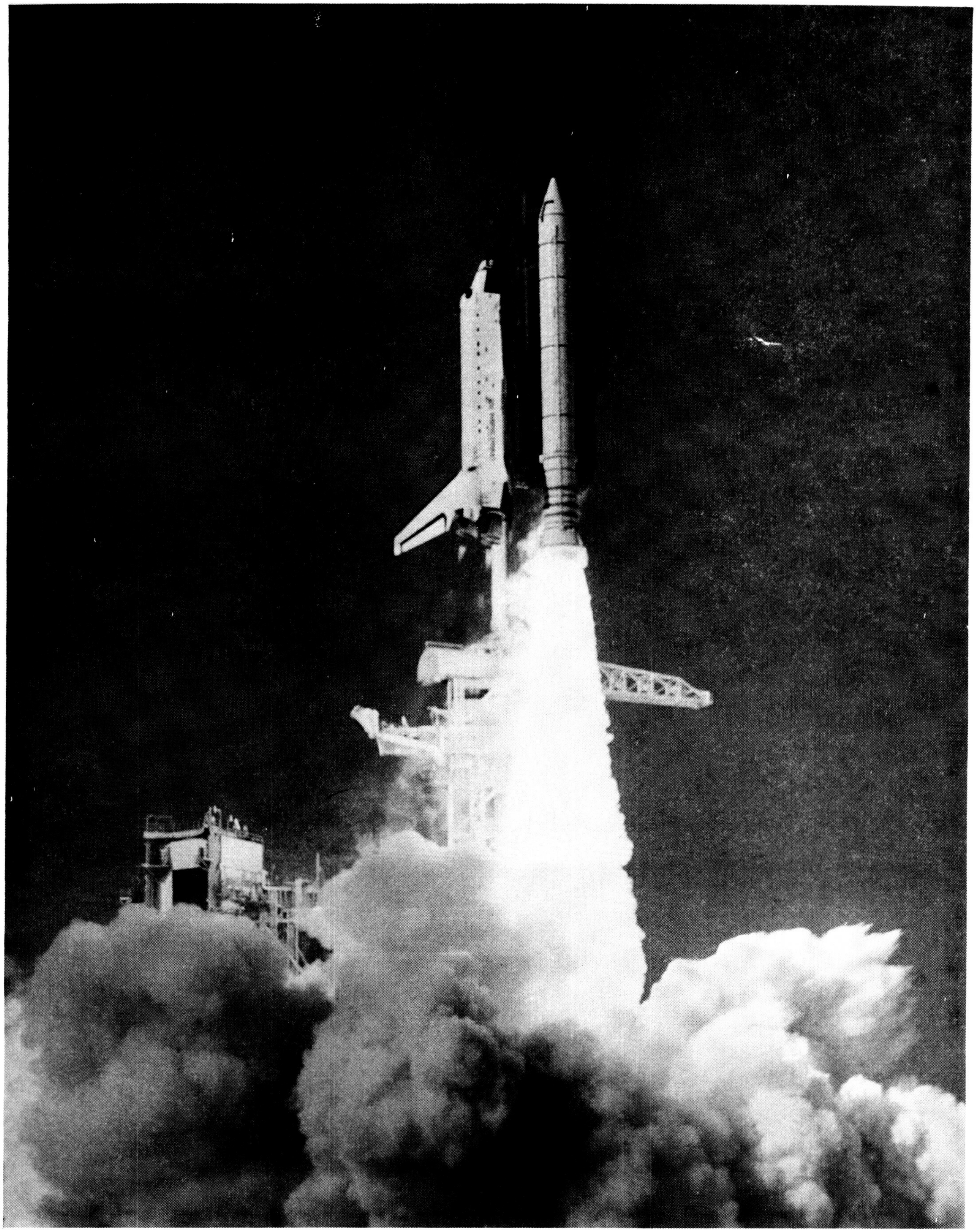
FORWARD

The Debris Team is continuing its effort to develop and implement measures to control damage from debris in the Shuttle operational environment and to make the control measures a part of routine processing and operations.



STS-27R LAUNCH

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1.0 Summary

Ice/Frost/Debris Team activities for Mission STS-27R began with the pre-launch debris inspection of the launch pad and Shuttle vehicle on 30 November 1988. No anomalies were observed on OV-104 Atlantis, BIO-30, or ET-23. Minor facility discrepancies, which included untorqued MLP deck bolts, loose bolt dome caps on the MLP rainbirds, and small quantities of trash under the raised deck plates and around the holddown posts, were corrected prior to cryo loading the vehicle.

The first launch attempt on 1 December 1988 was scrubbed at 0915 hours due to wind shears and high winds aloft. A 24 hour scrub turnaround was initiated. During the post drain inspection, no TPS damage, such as divots or cracks, was detected on the aft dome or tank acreage areas. Ice in the feedline bellows and support brackets had not yet melted. No 'hands-on' inspection of the LO2 feedline was possible due to the quick turnaround. No anomalies had occurred on the nosecone, tumble valve cover, or footprint area.

ET-23 was cryo-loaded for the second time on 2 December 1988. Infrared measuring devices recorded average temperatures (F) of 46.5 deg on the LO2 tank, 52 deg on the Intertank, 39 deg on the LH2 tank, 53 deg on the SRB cases, 66 deg on the SRB field joints, and 52.5 deg on the Orbiter surfaces. Typical accumulations of ice/frost were present in the LO2 feedline bellows and support brackets and on both ET/ORB umbilicals. Nine ice/frost console observation anomalies were documented and found acceptable for flight per the LCC and NSTS-08303. Ice and frost accumulations were less than usual compared to previous flights. At launch, the ET ice condition was well within the launch data base for ice formation. There were no Orbiter, SRB, or facility discrepancies with the exception of small frost fingers on the GOX vent ducts.

After a successful launch at 14:30:34 GMT, a post launch debris inspection of Pad 39B was performed. No significant flight hardware or TPS materials were found, though 1 Orbiter carrier panel Q-felt plug lay on the east side of the pad entrance. South holddown post shim material was intact, north holddown post doghouse blast covers had closed, and no shrapnel from HDP debris containers was found. Overall, the facility sustained minimal damage. Due to the unidentified debris object observed on television in the vicinity of the RH SRB shortly after separation, expanded debris inspections of the beaches continued for an additional 4 days in an effort to recover any potential debris that may have washed ashore. No flight hardware or TPS was recovered.

A total of 113 film and video items were analyzed as part of the post launch data review. No major vehicle damage or lost flight hardware was observed that would have affected the mission. A rectangular-shaped object is visible on several film

items at T+30 seconds MET that may have been the RH OMS pod carrier panel lost during ascent. Many pieces of debris fall from the vehicle during early ascent and most have been identified as SSME frost, RCS paper covers, and umbilical ice. But none of the remaining debris can be conclusively linked to the severe tile damage on the Orbiter. After SRB separation, two light colored objects are visible in the vicinity of the boosters. These objects are similar to pieces of 'slag' from the expended SRB's recorded on previous flights.

The recovered Solid Rocket Boosters exhibited minimal damage. The RH FWD assembly had 4 TPS debonds and 2 divots while the LH FWD assembly showed 4 TPS divots and no debonds. The TPS and Hypalon topcoat continues to have adhesion problems with widespread blistering, peeling, and cratering due to missing pieces. Some of the blisters revealed a combination of paint and MSA 1/32 to 1/16-inch thick indicating the formation of divots within the TPS. All factory and field joint closeouts were intact except for the RH center field joint. A 3.5-inch diameter divot to substrate, located at 185 degrees, was caused by entrapped air. Aft booster stiffener rings, ETA rings, and IEA structures were generally in good condition. The aft BSM nozzle rings continue to lose K5NA. The #3,4, and 5 debris plungers had not seated properly but may have been dislodged by water impact. Only Epon shim #8 showed signs of losing material during ascent.

The Orbiter post landing inspection was conducted 6 December 1988 on EAFB lakebed runway 17L. The Orbiter TPS sustained a total of 707 hits, of which 298 had a major dimension greater than 1-inch. This flight had the most extensive TPS damage to date. The severe damage was concentrated on the right lower surface outboard of a line from the bipod attachment to the ET/ORB LO2 umbilical. A tile over the L-band antenna cover was missing. The damage was a mixture of wide, shallow penetrations typically caused by low density material such as SOFI and long, deep gouges usually caused by higher density materials such as ice and MSA. ET nosecone, LO2 tank PAL ramp, and SRB nosecap were suspected as the sources of the tile damaging debris. Samples of SRB MSA-1/Hypalon topcoat were found embedded in some of the damaged tiles. The most probable cause of the severe tile damage on STS-27R was the ablative insulating material on the RH SRB nose cap dislodging and striking Orbiter tiles. It is highly probable that debris from other sources, such as ET TPS and ice from the 'exception' areas, caused additional minor tile damage. The integrity of the TPS on the STS-29R ET and SRB's was verified by plug pull testing. In an unrelated event, the RH OMS pod carrier panel over attach point #9 was lost during ascent due to improper installation.

2.0 KSC ICE/FROST/DEBRIS TEAM ACTIVITIES

Team Composition: NASA KSC, NASA MSFC, NASA JSC, LSOC SPC, RI - DOWNEY, MMMSS, USBI - BPC, MTI

Team Activities:

1) Prelaunch Pad Debris Inspection

Objective:	Identify and evaluate potential debris material/sources. Baseline debris and debris sources existing from previous launches.
Areas:	MLP deck, ORB and SRB flame exhaust holes, FSS, Shuttle vehicle external surfaces
Time:	L - 1 day
Requirements:	OMRSD S00U00.030 - An engineering debris inspection team shall inspect the shuttle and launch pad to identify/resolve potential debris sources. The prelaunch vehicle/pad configuration shall be documented/photographed.
Documents:	OMI S6444
Report:	Generate PR's and recommend corrective actions to pad managers.

2) Launch Countdown Firing Room 2

Objective:	Evaluate ice/frost accumulation on the shuttle vehicle and/or any observed debris utilizing OTV cameras.
Areas:	MLP deck, FSS, Shuttle vehicle external surfaces
Time:	T - 6 hours to Launch + 1 hour or propellant drainback
Requirements:	OMRSD S00FB0.005 - Monitor and video tape record ET TPS surfaces during loading through prepressurization. OMRSD S00FC0.021 - Monitor various areas of the ET from start of propellant loading through prepressurization.
Documents:	OMI S0007, OMI S6444
Report:	OIS call to NTD, generate IPR's.

3) Ice/Frost TPS and Debris Inspection

Objective: Evaluate any ice formation as potential debris material. Identify and evaluate any ORB, ET, or SRB TPS anomaly which may be a debris source or safety of flight concern. Identify and evaluate any other possible facility or vehicle anomaly.

Areas: MLP deck, FSS, Shuttle vehicle external surfaces

Time: T - 3 hours (during 2 hour BIH)

Requirements: OMRSD S00U00.020 - An engineering debris inspection team shall inspect the shuttle for ice/frost, TPS, and debris anomalies after cryo propellant loading. Evaluate, document, and photograph all anomalies. During shuttle walkdown inspect orbiter aft engine compartment (externally) for water condensation and/or ice formation in or between aft compartment tiles An IR scan is required during the shuttle inspection to verify ET surface temperatures. During shuttle walkdown, inspect ET TPS areas which cannot be observed by the OTV system.

Documents: OMI S0007, OMI S6444

Report: Briefing to NTD, Launch Director, Shuttle management; generate IPR's.

4) Post Launch Pad Debris Inspection

Objectives: Locate and identify debris that could have damaged the Shuttle vehicle during launch.

Areas: MLP deck, flame exhaust holes and trenches, FSS, pad surfaces and slopes, extension of trenches to perimeter fence, walkdown of the beach from Playlinda to Complex 40, aerial overview of inaccessible areas.

Time: Launch + 3 hours (after pad safing, before washdown)

Requirements: OMRSD S00U00.010 - An engineering debris inspection team shall perform a post launch pad/area inspection to identify any lost flight or ground systems hardware

and resultant debris sources. The post launch pad/area configuration shall be documented/photographed.

Documents: OMI S0007, OMI S6444

Report: Verbal briefing to LTD; generate PR's.

5) Launch Data Review

Objective: Detailed review of high speed films video tapes, and photographs from pad cameras and range trackers to determine possible launch damage to the flight vehicle. Identify debris and debris sources.

Time: Launch + 1 day to Launch + 6 days

Requirements: OMRSD S00U00.011 - An engineering film review and analysis shall be performed on all engineering launch film as soon as possible to identify any debris damage to the space shuttle vehicle. Identify flight vehicle or ground system damage that could affect orbiter flight operations or future SSV launches.

Documents: OMI S6444

Report: Results submitted to Intercenter Engineering Photo Analysis Committee; generate PR's.

6) SRB Post Flight/Retrieval Inspection

Objective: Evaluate potential SRB debris sources. Data will be correlated with observed Orbiter post landing TPS damage.

Areas: SRB external surfaces (Hangar AF, CCAFS)

Time: Launch + 24 hours (after on-dock, before hydrolasing)

Requirements: OMRSD S00U00.013 - An engineering debris damage inspection team shall perform a post retrieval inspection of the SRB's to identify any damage caused by launch debris. Any anomalies must be documented/ photographed and coordinated with the results of the post launch shuttle/pad area debris inspection.

Documents: OMI B8001

Report: Generate PR's.

7) Orbiter Post Landing Debris Damage Assessment

Objective: Identify and evaluate areas of damage to Orbiter TPS due to debris and correlate, if possible, source and time of occurrence. Additionally, the runway is inspected for debris and sources of debris.

Areas: Orbiter TPS surfaces, runway

Time: After vehicle safing on runway, before towing

Requirements: OMRSD S00U00.040 - An engineering debris inspection team shall perform a prelanding runway inspection to identify, document, and collect debris that could result in orbiter damage. Runway debris and any facility anomalies which cannot be removed/corrected shall be documented/photographed.

Requirements: OMRSD S00U00.050 - An engineering debris inspection team shall perform a post landing runway inspection to identify and resolve potential debris sources that may have caused vehicle damage but was not present or was not identified during pre-launch runway inspection. Obtain photographic documentation or any debris, debris sources, or flight hardware that may have been lost on landing.

Requirements: OMRSD S00U00.060 - An engineering debris inspection team shall map, document, and photograph debris-related Orbiter TPS damage and debris sources.

Requirements: OMRSD S00U00.012 - An engineering debris damage inspection team shall perform a post landing inspection of the orbiter vehicle to identify any damage caused by launch debris. Any anomalies must be documented/photographed and coordinated with the results of the post launch shuttle/pad area debris inspection.

Requirements: OMRSD V09AJ0.095 - An engineering debris inspection team shall perform temperature measurements of RCC Nose Cap and RCC RH Wing Leading Edge Panels 9 and 17.

Documents:	OMI S0026, OMI S0027, OMI S0028
Report:	Briefing to NASA Convoy Commander and generate PR's.

8) **Level II report**

Objective:	Compile and correlate data from all inspections and analyses. Results of the debris assessment, along with recommendations for corrective actions, are presented directly to Level II via SIR and PRCB. Paper copy of complete report follows in 3 to 4 weeks. (Ref NASA Technical Memorandum series).

3.0 PRE-TEST BRIEFING

The Ice/Frost/Debris Team briefing for launch activities was conducted on 30 November 1988 at 0830 hours with the following personnel present:

C. Stevenson	NASA - KSC	Chief, ET Mechanical Systems Lead, Ice/Debris Team
G. Katnik	NASA - KSC	ET Mech/TPS, Ice/Debris Assessment, STI
B. Speece	NASA - KSC	ET Processing, Ice Assess
B. Bowen	NASA - KSC	ET Processing, "SURFICE"
S. Higginbotham	NASA - KSC	STI, Debris Assessment
P. Feamster	NASA - KSC	ET Processing, Debris Assess
A. Oliu	NASA - KSC	"SURFICE", Debris Assess
M. Bassignani	NASA - KSC	ET Processing, Ice Assess
R. Stevens	NASA - KSC	SRB Stacking, Disassembly
Z. Byrns	NASA - JSC	Level II Integration
F. Huneidi	NASA - MSFC	TPS & Ice Assessment
D. Andrews	NASA - MSFC	Debris Assessment
J. Hoffman	LSOC - SPC	ET Processing, Ice Assess
R. Seale	LSOC - SPC	ET Processing, Ice Assess
M. Young	LSOC - SPC	ET Processing, Ice Assess
J. Cawby	LSOC - SPC	ET Processing, Ice Assess
C. Gray	MMC - MAF	ET TPS & Materials Design
R. Huber	MMC - MAF	ET TPS Testing/Certif
J. McClymonds	RI - Downey	Support LVL II Integration
L. Zook	USBI - PSE	SRB Processing
J. Maw	MTI - Utah	SRM Plant Representative
G. Woods	NASA - SSC	STI Checkout
G. Meeks	NASA - SSC	STI Installation

3.1 PRE-LAUNCH SSV/PAD DEBRIS INSPECTION

The pre-launch debris inspection of the pad and Shuttle vehicle was conducted on 30 November 1988 from 1000 - 1300 hours. The detailed walkdown of Launch Pad 39B and MLP-1 also included the primary flight elements OV-104 Atlantis (3rd flight), ET-23 (LWT-16), and BIO-30. Documentary photographs were taken of facility anomalies, potential sources of vehicle damaging debris, and new vehicle configurations.

Bolts were not torqued on the SRB servicing access deck plate west of holddown post #8, the ESP electrical access box 15 feet west of the LH SRB flame hole, the access cover plate underneath the sound suppression water pipe near holddown post #7, on the electrical hook-up cover panel on the west MLP deck under the water pipe, on the hand rail holddown posts along the MLP deck north and east sides, and on the grounding straps near holddown posts #5 and #7.

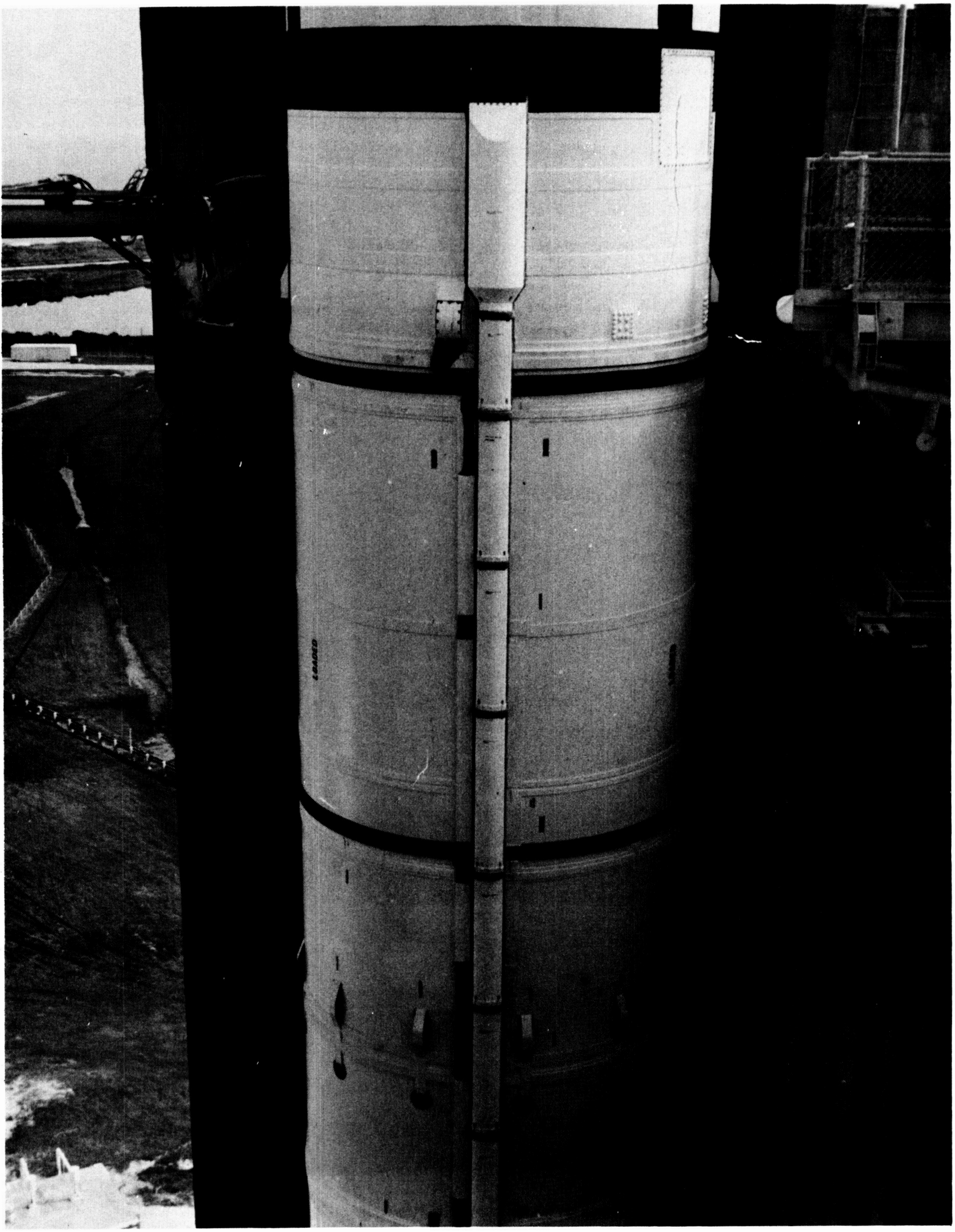
Covers on an electrical box (MLP southwest corner) and OIS outlet (MLP southeast and east sides) were loose. One hole plug from MLP deck cover #18 was missing.

A safety lanyard attachment was loose on the downward water spout located on the west side of the RH SRB exhaust hole. An end plug from the MLP west side sound suppression water pipe was removed and hanging by a tether.

A few bolt dome caps were loose on the MLP deck rainbirds. Subsequent checks revealed about 30 caps were loose enough to possibly be dislodged by the SRB plume. These caps were removed prior to launch.

Small particles of trash lay under the raised deck plates and metal filings were scattered near holddown post #1.

Although the cleanup of the MLP deck and pad surface was still in progress at the time of the inspection, overall cleanliness was considered good. Launch pad managers were briefed on the facility discrepancies listed above for resolution prior to vehicle tanking.



LH SRB CABLE TRAY AND DFI CLOSEOUTS

ORBITER LEFT WING LOWER SURFACE

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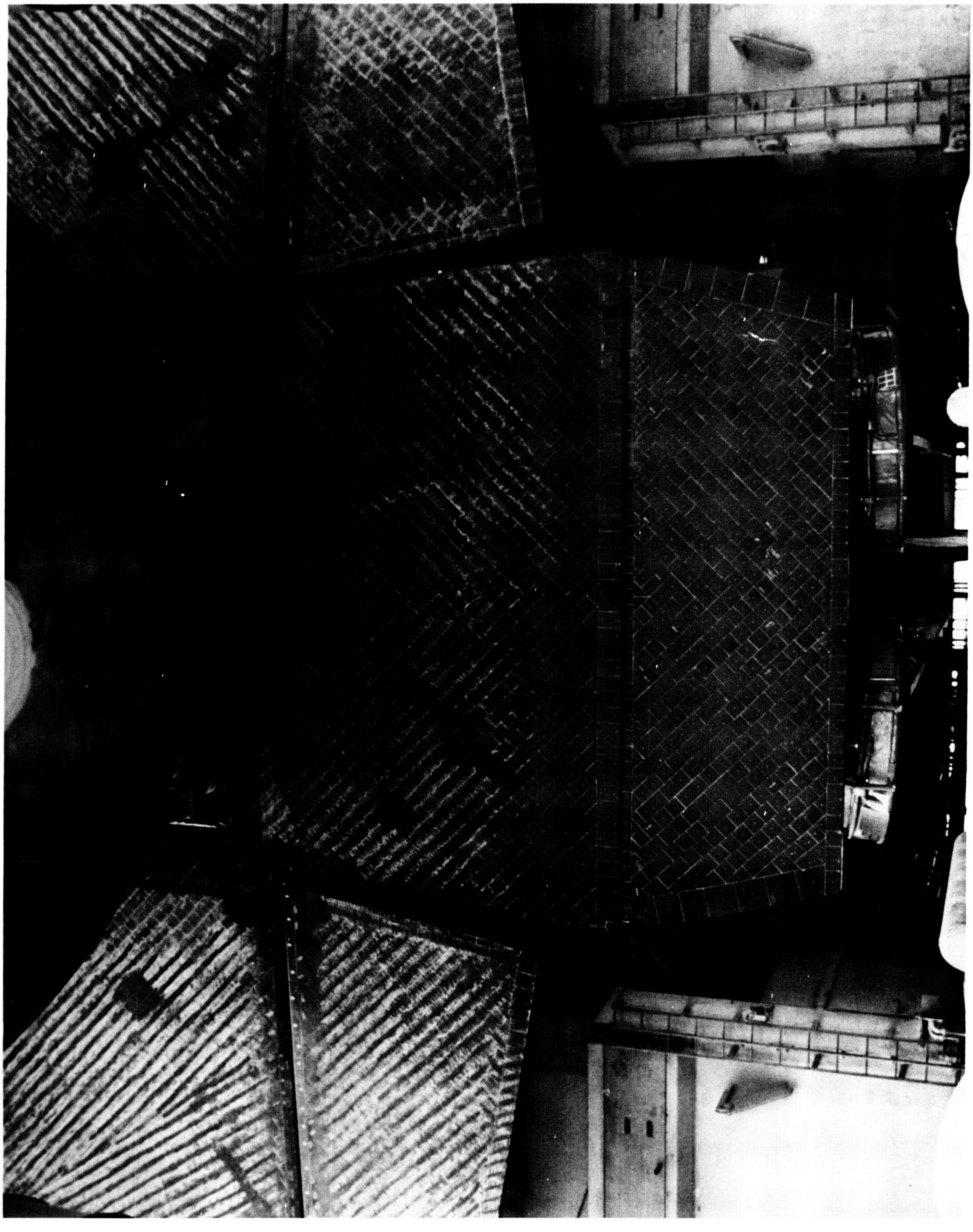

ORBITER AFT LOWER SURFACE

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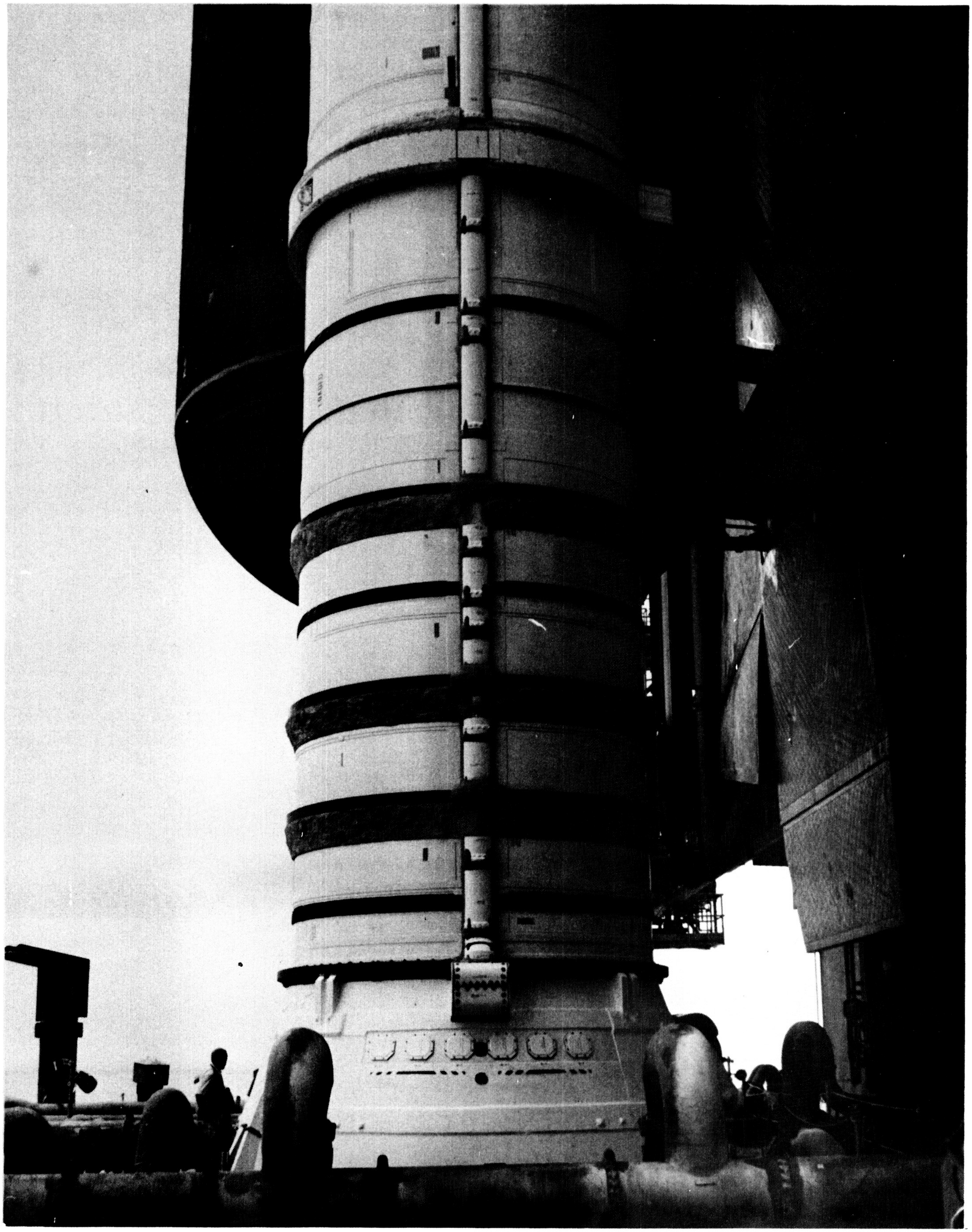

LH SRB AFT BOOSTER WITH K5NA CLOSEOUTS

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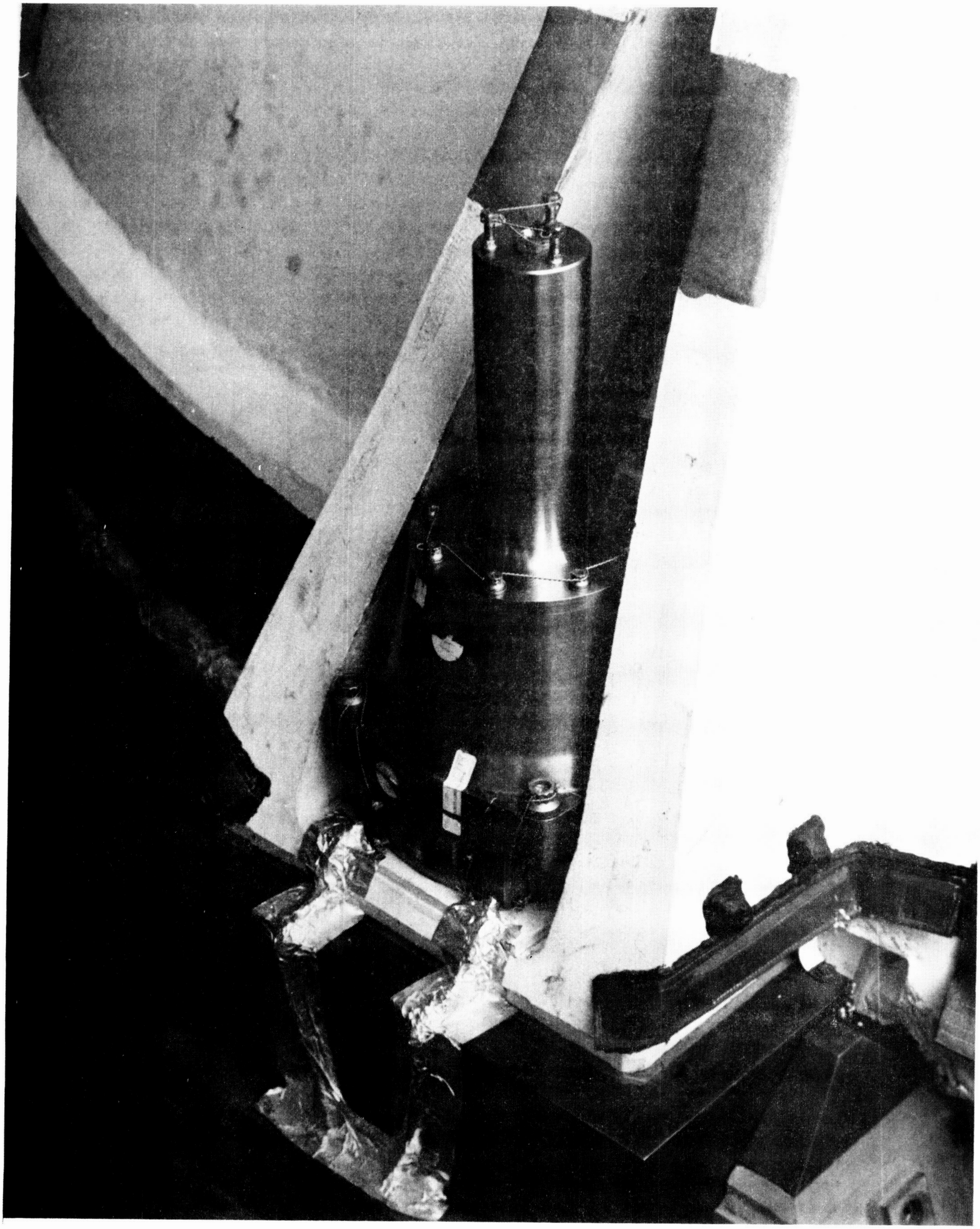

HOLDDOWN POST DEBRIS CONTAINER. NON-CHAMFERED SHOE.

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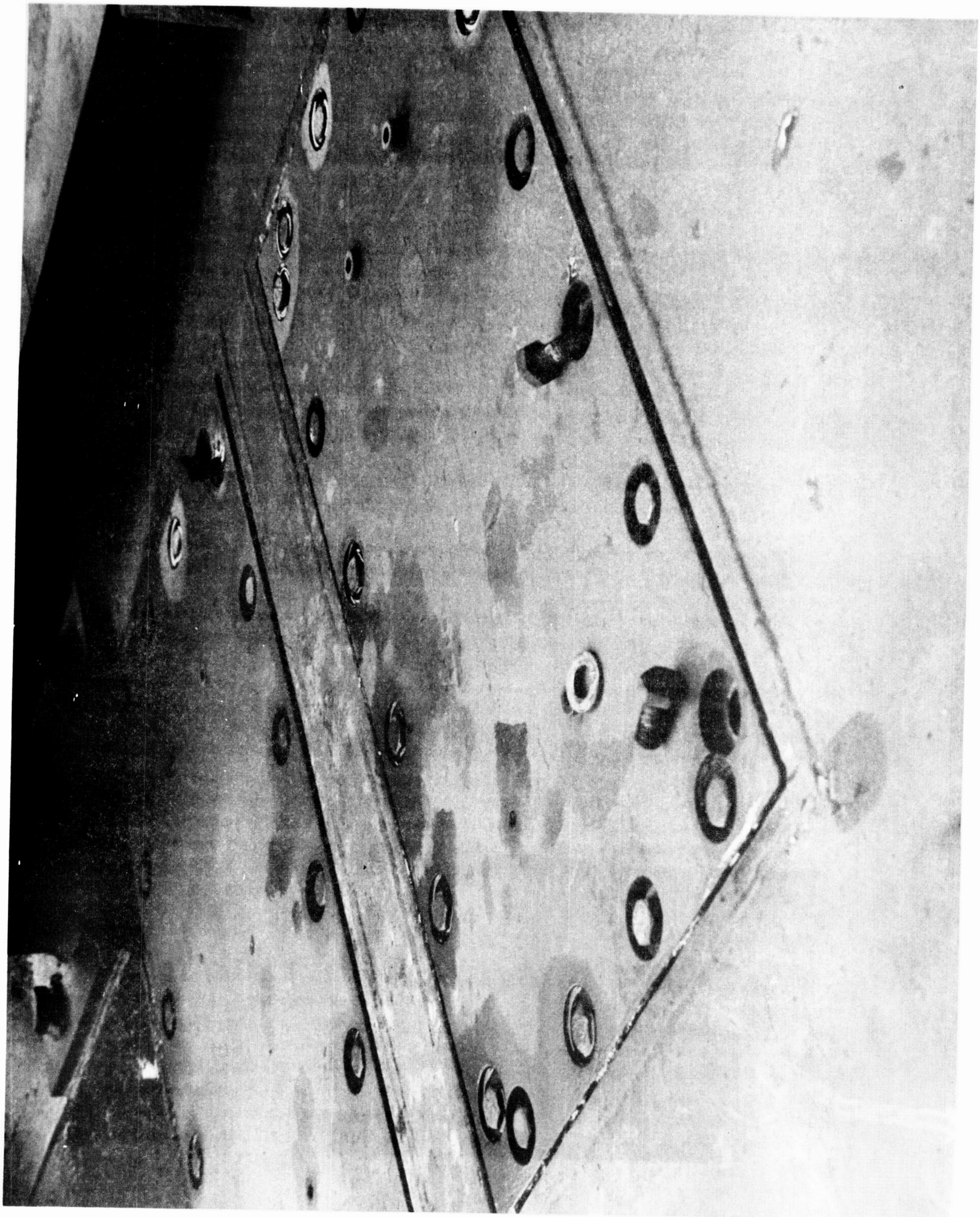

LOOSE ACCESS PLATE BOLTS ON MLP DECK

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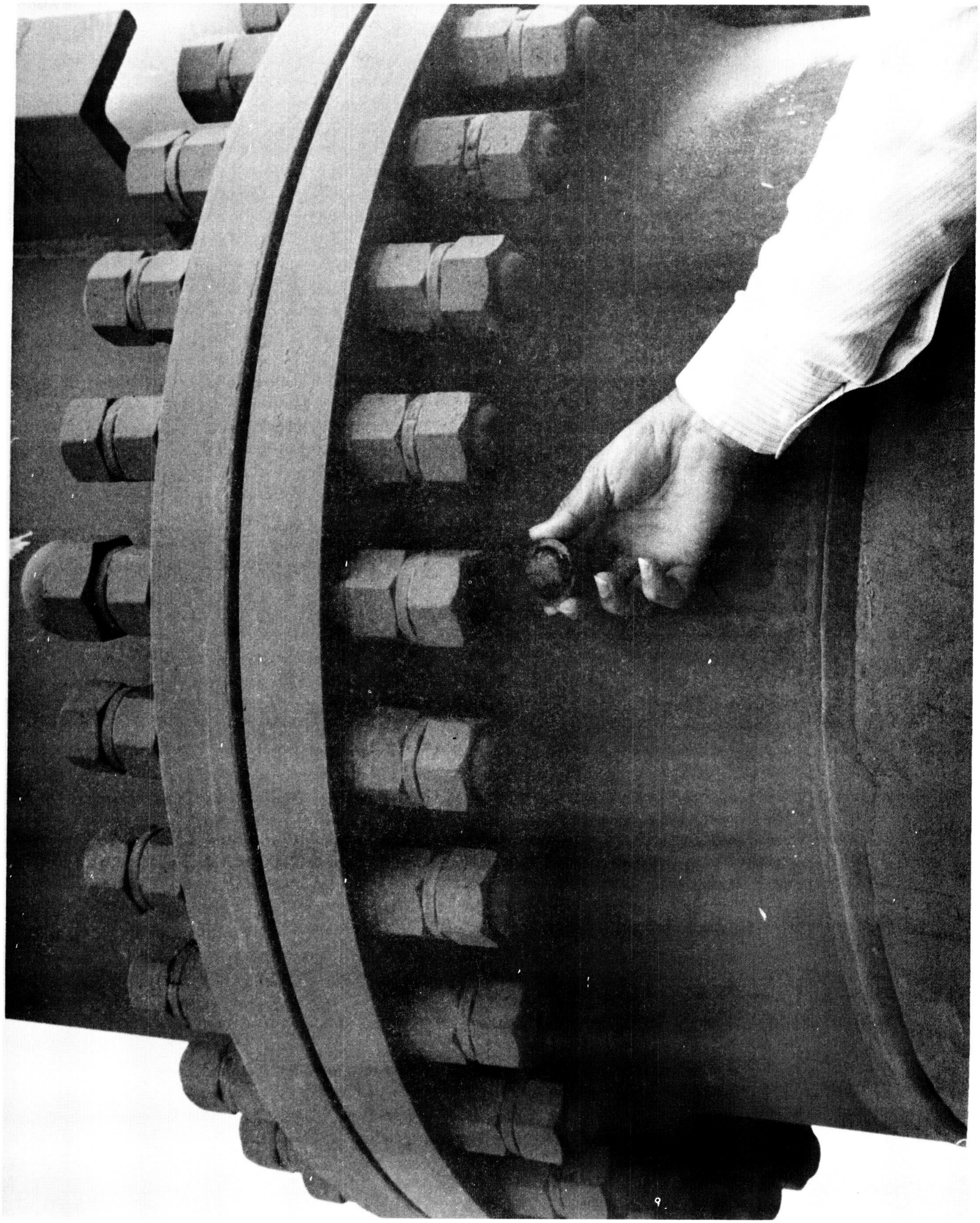

LOOSE DOME CAP ON SOUND SUPPRESSION SYSTEM RAINBIRD BOLT

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COLLECTION OF DETATCHED BOLT DOME CAPS

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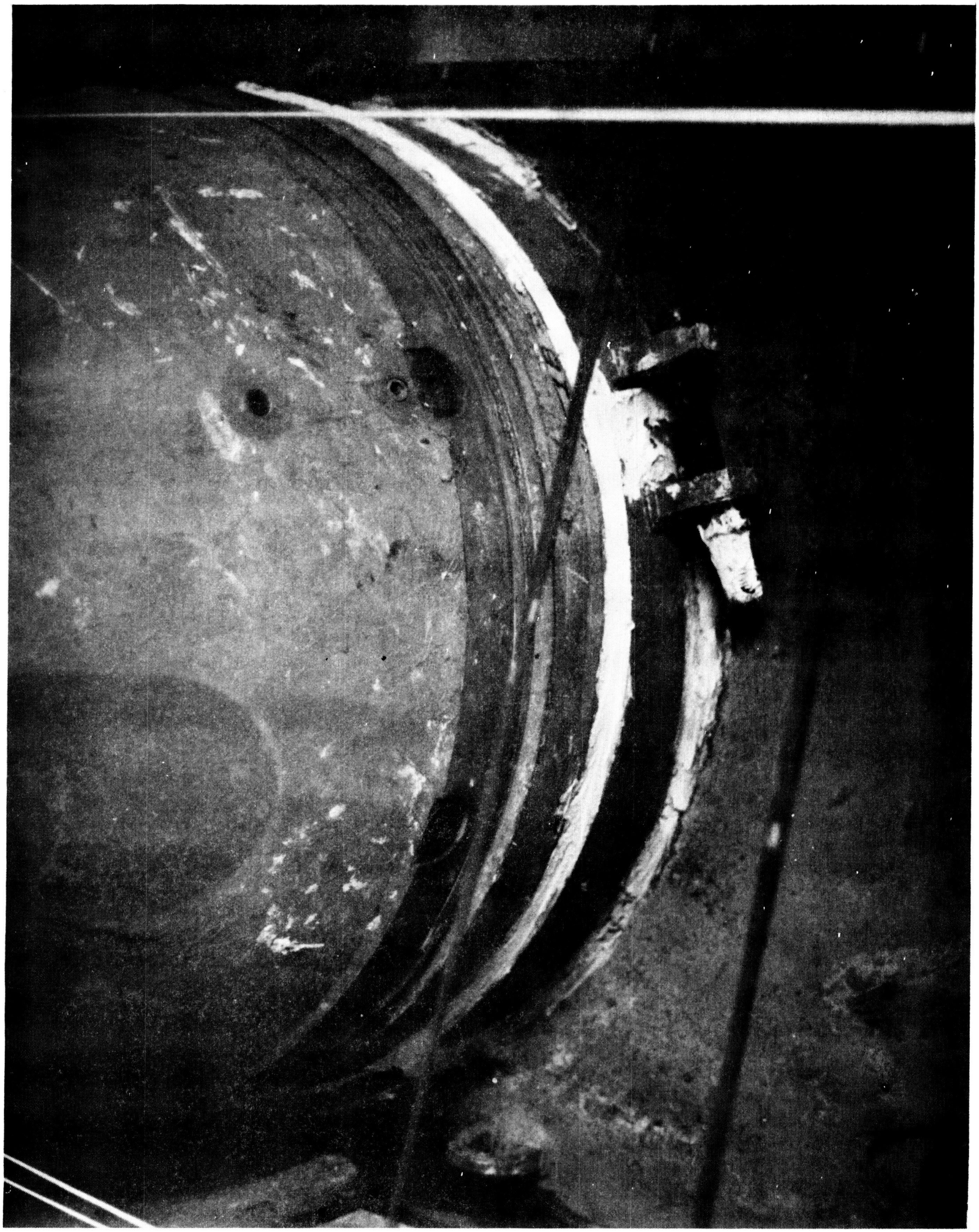


EXCESSIVE RTV ON HOLDDOWN POST STRAIN GAGE BELLY BAND

4.0 LAUNCH SCRUB (winds aloft)

The launch attempt on 1 December 1988 was scrubbed at 0915 hours due to high winds and wind shears aloft. A 24 hour scrub turnaround was initiated.

4.1 ICE/FROST INSPECTION

The Ice/Frost Inspection of the cryoloaded vehicle was performed on 1 December 1988 from 0218 to 0410 hours during the two hour built-in-hold at T-3 hours in the countdown. There were no violations of NSTS-08303 or the Launch Commit Criteria. Ambient weather conditions at the time of the inspection were:

Temperature:	69 F
Relative Humidity:	74 %
Wind Speed:	15 Knots
Wind Direction:	016 Degrees

Following the checkout and validation of the Shuttle Thermal Imager (STI) system during STS-26R operations, the Ice Team utilized this new equipment to obtain surface temperature measurements in the overall thermal assessment of the vehicle. The measurements, presented in Figures 1 and 2, are a summary of data from the STI portable system which accompanied the Ice Team during the Ice Inspection.

4.2 ORBITER OBSERVATIONS

No Orbiter tile anomalies were observed. The average Orbiter surface temperature was recorded as 66 degrees F. The surface temperatures of the SSME engine mounted heat shields were recorded as 42 degrees F for SSME #1 and 51 degrees F for SSME #3. No ice was present on the engine to heat shield interfaces of the SSMEs, but condensate was observed on all three.

4.3 SRB OBSERVATIONS

No SRB anomalies were observed. The STI portable infrared scanner recorded LH SRB surface temperatures between 67 to 69 degrees F while temperatures on the RH SRB ranged from 66 to 69 degrees F. A temperature of 75 degrees F was recorded for each of the the SRB field joints except for the LH center field joint which was recorded at 80 degrees F. The predicted Propellant Mean Bulk Temperature (PMBT) supplied by MTI was 69 degrees F.

FIGURE 1. **INFRA-RED SCANNER SSV SUMMARY DATA**

TIME: 0218 - 0410 EST
DATE: 1 December 1988
VEH. STS- 27R

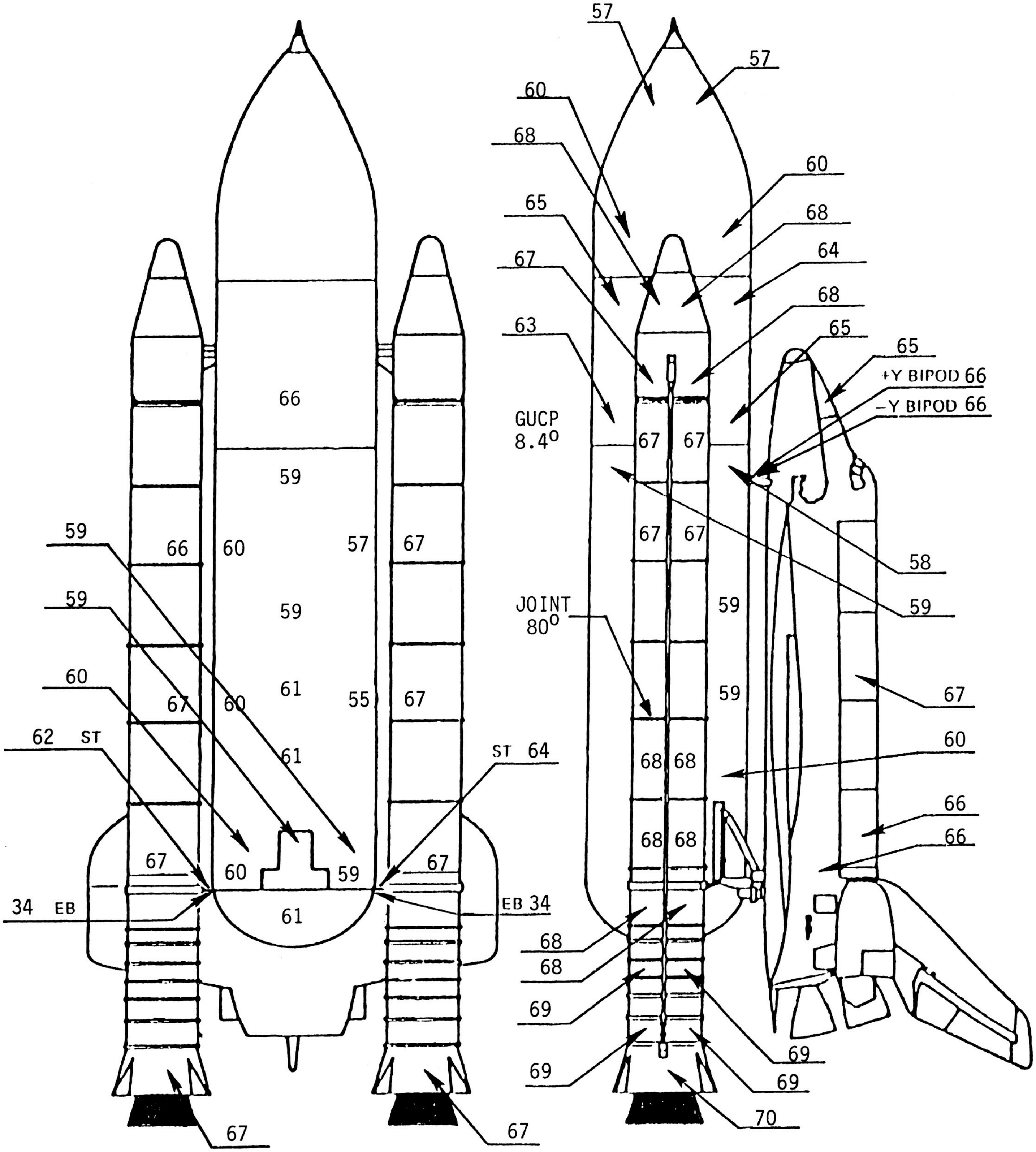
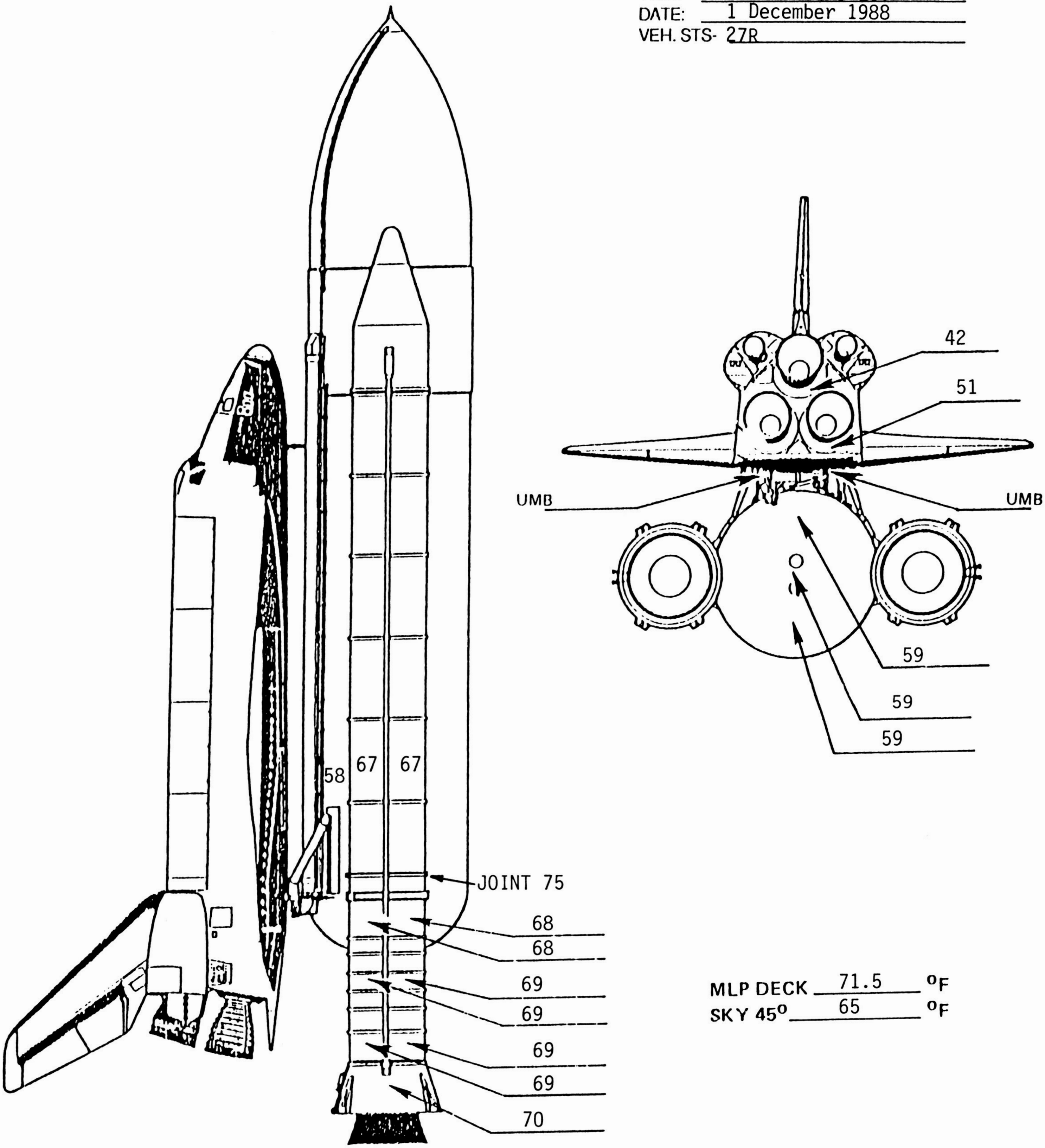


FIGURE 2. **INFRA-RED SCANNER SSV SUMMARY DATA**

TIME: 0218 - 0410 EST

DATE: 1 December 1988

VEH. STS- 27R



MLP DECK 71.5 °F

SKY 45° 65 °F

4.4 EXTERNAL TANK OBSERVATIONS

No acreage ice and minimal condensate was present on the LO2 tank, Intertank, and LH2 tank. The IR scanner measured an average surface temperature of 57 degrees F on the LO2 tank ogive, 60 degrees F on the LO2 tank barrel, 65 degrees F on the Intertank, 59 degrees F on the upper and lower LH2 tank.

Two small ice/frost balls were observed on the LH2 tank. The first was located on the -Z third hardpoint and had a diameter of approximately 1/2 inch. The second was located on the aft dome manhole closeout and was approximately 3/4 inch in diameter. Both of these conditions are acceptable per NSTS-08303.

Ice/Frost covered the lower EB fittings outboard to the strut pin hole with condensate dripping from the rest of the fitting. The EB struts were dry and were not covered by ice.

Normal icing conditions were observed on the LO2 feedline and pressurization line barrymounts with small frost areas forming on the aft surface of the ramps. Ice/frost was present on all the LO2 feedline bellows and support brackets.

The LO2 ET/ORB umbilical was free of ice except for frost fingers on the purge vents. Ice/frost had formed in the LH2 ET/ORB recirculation line bellows, purge vents, and in an area on the aft side of the baggie. Overall, the LO2 and LH2 ET/ORB umbilicals had a less than usual amount of ice/frost build-up.

The tumble valve cover was intact and not protruding.

The ice prediction computer program was run from 2330 to 0900 hours and the results tabulated in Figures 3, 4, and 5. The program predicted condensate with no ice accumulation on all TPS acreage.

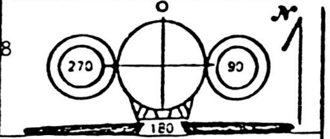
The scrub summary of ice/frost console observation anomalies consists of one Ice Team inspection item and 7 OTV recorded items:

Anomaly 001 documented a frost line between the manhole cover closeout and the aft dome acreage. Frost was present at T-3 hours, but was not visible on OTV cameras at T-20 minutes.

Frost build-up on the LO2 feedline support struts at XT-1129, 1362, 1609, and 1871 (Anomaly 002) was acceptable per the NSTS-08303 criteria.

The formation of frost on the northern GOX vent exhaust duct was recorded on Anomaly 003 and IPR 27R-0493 was issued by CMEC. Most of the GOX vapors were flowing from the northern duct compared to no activity from the southern duct.

STS-27R	TEST: S0007, LAUNCH (SCRUB)				DATE: 12/01/88	T-0 TIME: N/A DATE: 12/01/88
ORBITER OV-104	ET 23	SRB BI030	MLP 1	PAD 39B	LO2 CHILLDOWN TIME: 2320 FAST FILL TIME: 0009 SLOW FILL TIME: 2355 REPLENISH TIME: 0210	LH2 CHILLDOWN TIME: 2322 FAST FILL TIME: 2359 SLOW FILL TIME: 2330 REPLENISH TIME



LOCAL TIME	CONDITIONS					LO2 TANK STA 370 TO 540					LO2 TANK STA 550 TO 852					LH2 TANK STA 1130 TO 1380					LH2 TANK STA 1380 TO 2058				
	TEMP. °F	REL HUM. %	DEW PT °F	WIND VEL KNTS	WIND DIR DEG	REGION	LOCAL VEL KNTS	SOFI TEMP °F	COND RATE IN/HR	ICE RATE IN/HR	REGION	LOCAL VEL KNTS	SOFI TEMP °F	COND RATE IN/HR	ICE RATE IN/HR	REGION	LOCAL VEL KNTS	SOFI TEMP °F	COND RATE IN/HR	ICE RATE IN/HR	REGION	LOCAL VEL KNTS	SOFI TEMP °F	COND RATE IN/HR	ICE RATE IN/HR
2330	71.4	84.2	66.55	10	19		5.90	62.61	+.0024	-.2032		5.90	58.89	.0043	-.1722		4.40	55.68	.0045	-.1217		9.90	61.55	.0047	-.2835
2345	71	85.2	66.48	12	21		7.08	63.12	.0025	-.2367		7.08	59.91	.0044	-.2052		5.28	57.04	.0047	-.1465		11.88	62.28	.0047	-.3378
0000	71	85.4	66.55	13	17		7.67	63.45	.0024	-.2546		7.67	60.45	.0045	-.2228		5.72	57.74	.0048	-.1599		12.87	62.7	.0047	-.3666
0015	71	84	66.09	13	15		7.67	63.14	.0023	-.2513		7.67	60.13	.0043	-.2196		5.72	57.41	.0046	-.1574		12.37	62.37	.0045	-.3615
0030	71	82.6	65.62	13	13		7.67	62.82	.0021	-.2480		7.67	59.80	.0041	-.2164		5.72	57.09	.0045	-.1550		12.87	62.05	.0042	-.3564
0045	70.8	82.4	65.35	13	19		7.67	62.57	.0021	-.2453		7.67	59.53	.0041	-.2138		5.72	56.81	.0044	-.1529		12.87	61.79	.0042	-.3525
0100	70.4	82.4	64.95	13	15		7.67	62.15	.0021	-.2410		7.67	59.1	.0041	-.2096		5.72	56.36	.0044	-.1496		12.87	61.37	.0042	-.3461
0115	68	90.2	65.1	14	10		8.26	61.56	.0028	-.2489		8.26	58.66	.0048	-.2173		6.16	55.96	.0050	-.1546		13.86	60.91	.0052	-.3608
0130	69.2	84.8	64.57	17	17		10.03	62.31	.0022	-.2980		10.03	59.87	.0042	-.2658		7.48	57.55	.0046	-.1917		16.83	61.78	.0041	-.4396
0145	69.6	80.6	63.54	17	13		10.03	61.79	.0016	-.2912		10.03	59.32	.0037	-.2593		7.48	57.03	.0042	-.1868		16.83	61.22	.0034	-.4289
0200	69.2	80.0	62.94	16	13		9.44	61.04	.0016	-.2691		9.44	58.44	.0036	-.2375		7.04	56.03	.0041	-.1702		15.84	60.44	.0033	-.3938
0215	69.4	76.6	61.93	17	18		10.03	60.68	.0011	-.2772		10.03	58.18	.0031	-.2456		7.48	55.88	.0037	-.1763		16.83	60.09	.0025	-.4074
0230	69	73.4	60.35	15	11		8.85	59.14	.0089	-.2347		8.85	56.32	.0028	-.2040		6.60	53.79	.0034	-.1445		14.85	58.43	.0022	-.3399
0245	69	74	60.57	16	10		9.44	59.49	.0009	-.2506		9.44	56.82	.0028	-.2196		7.04	54.4	.0034	-.1564		15.84	58.83	.0022	-.3655
0300	69.2	74.8	61.07	15	26		8.85	59.67	.0011	-.2405		8.85	56.86	.0030	-.2096		10.50	57.31	.0032	-.2442		18.15	59.73	.0019	-.4270

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FIGURE 3. Ice/Frost Computer Predictions

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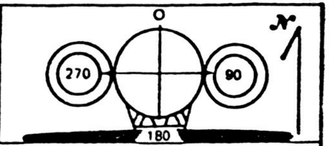
STS-27R	TEST: S0007, LAUNCH (SCRUB)					DATE: 12/01/88	T-0 TIME: N/A DATE 12/01/88
ORBITER OV- 104	ET 23	SRB BI030	MLP 1	PAD 39B	LO$_2$ CHILLDOWN TIME: 2320 SLOW FILL TIME: 2355 FAST FILL TIME: 0009 REPLENISH TIME: 0210	LH$_2$ CHILLDOWN TIME: 2322 SLOW FILL TIME: 2330 FAST FILL TIME: 2359 REPLENISH TIME:	



LOCAL TIME	CONDITIONS					LO$_2$ TANK STA 370 TO 540					LO$_2$ TANK STA 550 TO 852					LH$_2$ TANK STA 1130 TO 1380					LH$_2$ TANK STA 1380 TO 2058				
	TEMP. °F	REL HUM. %	DEW PT °F	WIND VEL. KNTS	WIND DIR DEG	REGION	LOCAL VEL KNTS	SOFI TEMP °F	COND RATE IN/HR	ICE RATE IN/HR	REGION	LOCAL VEL KNTS	SOFI TEMP °F	COND RATE IN/HR	ICE RATE IN/HR	REGION	LOCAL VEL KNTS	SOFI TEMP °F	COND RATE IN/HR	ICE RATE IN/HR	REGION	LOCAL VEL KNTS	SOFI TEMP °F	COND RATE IN/HR	ICE RATE IN/HR
0315	69	74.4	60.72	14	19		8.26	59.14	.0011	-.2228		8.26	56.16	.0030	-.1922		6.16	53.5	+.0035	-.1356		13.86	58.37	.0026	-.3205
0330	69.4	73.4	60.74	16	13		9.44	59.75	.0008	-.2536		9.44	57.1	.0028	-.2225		7.04	54.69	.0034	-.1587		15.84	59.09	.0021	-.3699
0345	69.4	74.2	61.04	13	15		7.67	59.24	.0012	-.2117		7.67	56.09	.0031	-.1813		5.72	53.31	.0035	-.1275		12.87	58.4	.0027	-.3022
0400	68.8	74.8	60.68	13	11		7.67	59.76	.0013	-.2072		7.67	55.69	.0031	-.1768		5.72	52.78	.0036	-.1239		12.87	57.92	.0028	-.2955
0415	68.8	73.8	60.3	18	21		10.62	59.60	.0006	-.2760		10.62	57.18	.0026	-.2447		7.92	54.95	.0033	-.1753		17.82	59.03	.0018	-.4070
0430	69.2	70.2	59.31	16	11		9.44	58.79	.0004	-.2426		9.44	56.12	.0023	-.2119		7.04	53.71	.0030	-.1505		15.84	58.12	.0014	-.3532
0445	68.6	71.2	59.16	15	4		8.85	58.23	.0006	-.2246		8.55	55.38	.0025	-.1944		6.6	52.83	.0031	-.1371		14.85	57.5	.0018	-.3251
0500	65.2	88.4	61.76	11	4		6.69	57.22	.0026	-.1711		6.49	53.52	.0043	-.1412		4.84	50.21	.0044	-.0957		10.89	56.30	.0048	-.2398
0515	65.8	87.8	62.17	12	4		7.08	58.12	.0025	-.1901		7.08	54.69	.0043	-.1598		5.28	51.59	.0045	-.1100		11.88	57.29	.0047	-.2696
0530	66.8	84.6	62.12	9	9		5.31	57.25	.0023	-.1488		5.31	52.96	.0040	-.1192		3.96	49.3	.0041	-.0796		8.91	56.02	.0044	-.2025
0545	67	78.8	60.35	13	2		7.67	57.79	.0017	-.1982		7.67	54.57	.0035	-.1680		5.72	51.69	.0038	-.1166		12.87	56.98	.0034	-.2827
0600	68.4	68	57.64	19	23		11.21	58.4	.00	-.2671		11.21	55.64	.0016	-.2363		13.30	56.04	.0016	-.2763		22.99	58.69	0	-.4834
0615	68.2	65.8	56.54	18	21		10.62	57.8	0	-.2453		10.62	54.64	.0014	-.2149		7.92	52.39	.0023	-.1523		17.82	56.51	0	-.3600
0630	68.4	65.4	56.57	16	12		9.44	57.17	0	-.2210		9.44	54.12	.0016	-.1910		7.04	51.67	.0024	-.1342		15.84	56.16	.0005	-.3205
0645	68.4	65.6	56.65	17	24		10.03	57.61	0	-.2343		10.03	54.50	.0015	-.2041		11.90	54.92	.0015	-.2385		20.57	57.81	0	-.9197

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FIGURE 4. Ice/Frost Computer Predictions

STS-27R

TEST: S0007, LAUNCH (SCRUB)

DATE: 12/01/88

T-0 TIME: N/A DATE 12/01/88

ORBITER OV- 104

ET 23

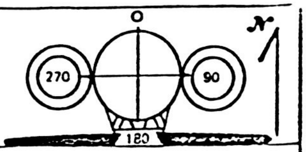
SRB BI030

MLP 1

PAD 39B

LO$_2$ CHILLDOWN TIME: 2320 SLOW FILL TIME: 2355 FAST FILL TIME: 0009 REPLENISH TIME: 0210

LH$_2$ CHILLDOWN TIME: 2322 SLOW FILL TIME: 2330 FAST FILL TIME: 2359 REPLENISH TIME:



LOCAL TIME	CONDITIONS					LO$_2$ TANK STA 370 TO 540					LO$_2$ TANK STA 550 TO 852					LH$_2$ TANK STA 1130 TO 1380					LH$_2$ TANK STA 1380 TO 2058				
	TEMP °F	REL HUM %	DEW PT °F	WIND VEL KNTS	WIND DIR DEG	REGION	LOCAL VEL KNTS	SOFI TEMP °F	COND RATE IN/HR	ICE RATE IN/HR	REGION	LOCAL VEL KNTS	SOFI TEMP °F	COND RATE IN/HR	ICE RATE IN/HR	REGION	LOCAL VEL KNTS	SOFI TEMP °F	COND RATE IN/HR	ICE RATE IN/HR	REGION	LOCAL VEL KNTS	SOFI TEMP °F	COND RATE IN/HR	ICE RATE IN/HR
0700	68	65.6	56.26	18	32		10.62	57.39	0	-.2424		10.62	54.39	.0014	-.2121		12.60	54.80	.0013	-.2481		21.78	57.88	0	-.4365
0715	68.2	65	56.21	14	22		8.26	56.12	.0001	-.1926		8.26	53.05	.0018	-.1129		6.16	50.36	.0025	-.1129		13.86	55.29	.0009	-.2749
0730	68.4	63.8	55.89	20	19		11.80	58.66	0	-.2666		11.80	54.86	.0009	-.2360		8.80	52.78	.0019	-.1683		19.80	57.50	0	-.3948
0745	68.4	66.4	56.99	17	24		10.03	57.63	0	-.2366		10.03	54.69	.0017	-.2062		11.90	55.11	.0016	-.2410		20.57	57.83	0	-.4238
0800	68.4	67.4	57.4	14	27		8.26	56.89	.0003	-.2001		8.26	53.85	.0021	-.1703		9.80	54.31	.0022	-.1987		16.94	56.91	.0006	-.3520
0815	68.4	66	56.82	15	15		8.85	56.79	0	-.2097		8.85	53.91	.0018	-.1798		6.60	51.35	.0026	-.1258		14.85	56.04	.0008	-.3021
0830	68.4	69.4	58.21	12	12		7.08	56.8	.0008	-.1778		7.08	53.36	.0026	-.1482		5.28	50.38	.0030	-.1019		11.88	55.84	.0021	-.2799
0845	68.6	69.6	58.48	17	17		10.03	58.24	.0002	-.2478		10.03	55.68	.0021	-.2171		7.48	53.35	.0029	-.1592		16.83	57.61	.0011	-.3625
0900	68.6	67.6	57.68	16	17		9.44	57.58	.0001	-.2290		9.44	54.87	.0019	-.1987		7.04	52.43	.0027	-.1402		15.84	56.89	.0009	-.3326
AVG.	68.9	75.3	60.82	15	16 NNE			59.38					56.39					54.22					58.76		

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FIGURE 5. Ice/Frost Computer Predictions

Anomaly 004 documented vapors emanating from the GUCP shroud area and a leak detector reported the maximum concentration of hydrogen had been exceeded during LH2 topping. After the stable replenish mode had been reached, the leakage rate fell within acceptable limits. Although IPR 27R-0473 was written against the leak, no ice/frost debris concerns were present at launch. Post launch investigation of the leak on the IPR revealed an "O"-ring had been left out of the quick disconnect during assembly. This problem is being corrected for future flights.

During LO2 fast fill, vapors emanated from the LO2 feedline bellows at station XT-1890 and frost had formed within 1 hour. (Anomaly 005). The vapors occur from the convective cooling of the bellows surface and is an explained condition.

A 3/4-inch diameter frost spot in the aft hardpoint pad closeout was recorded on Anomaly 006. This is not an ice debris area of concern and is acceptable per NSTS-08303.

Anomaly 007 documented a 2-3 inch ice/frost finger on the LH2 ET/ORB umbilical purge vent, a 3-inch area of ice formation on the baggie, and light frost in the recirculation line bellows. These items fall within the accepted data base of NSTS-08303.

Similarly, a 3-4 inch frost finger on the ET/ORB LO2 umbilical purge vent (Anomaly 008) was acceptable.

4.5 FACILITY OBSERVATIONS

All debris concerns previously identified had been resolved prior to cryoloading and no new items were noted during the walkdown. No leaks were observed on either the LO2 or LH2 ORB T-0 umbilicals. There was also no apparent leakage anywhere on the GH2 vent line or GUCP. The modification to the GH2 vent line prevented any ice from forming but some frost, which was expected, had accumulated on the GUCP. Visual and infrared observations of the GOX seals confirmed no leakage. Small frost fingers had formed on the GOX vent ducts.

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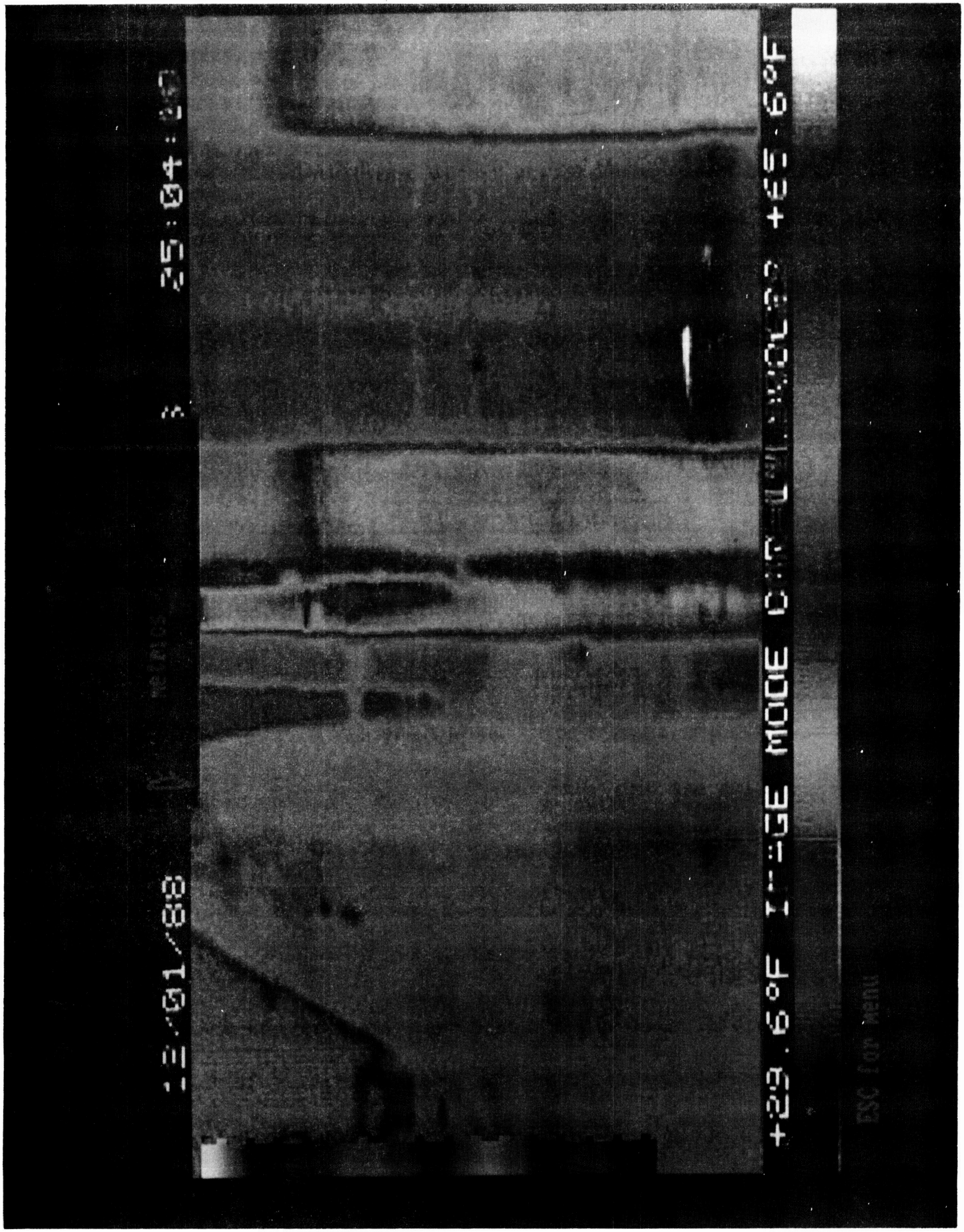

INFRARED IMAGE OF VEHICLE +Y SIDE AS VIEWED BY C/S-2 STI UNIT.
NO ANOMALIES VISIBLE. NOTE HEATED SRB FIELD JOINT.

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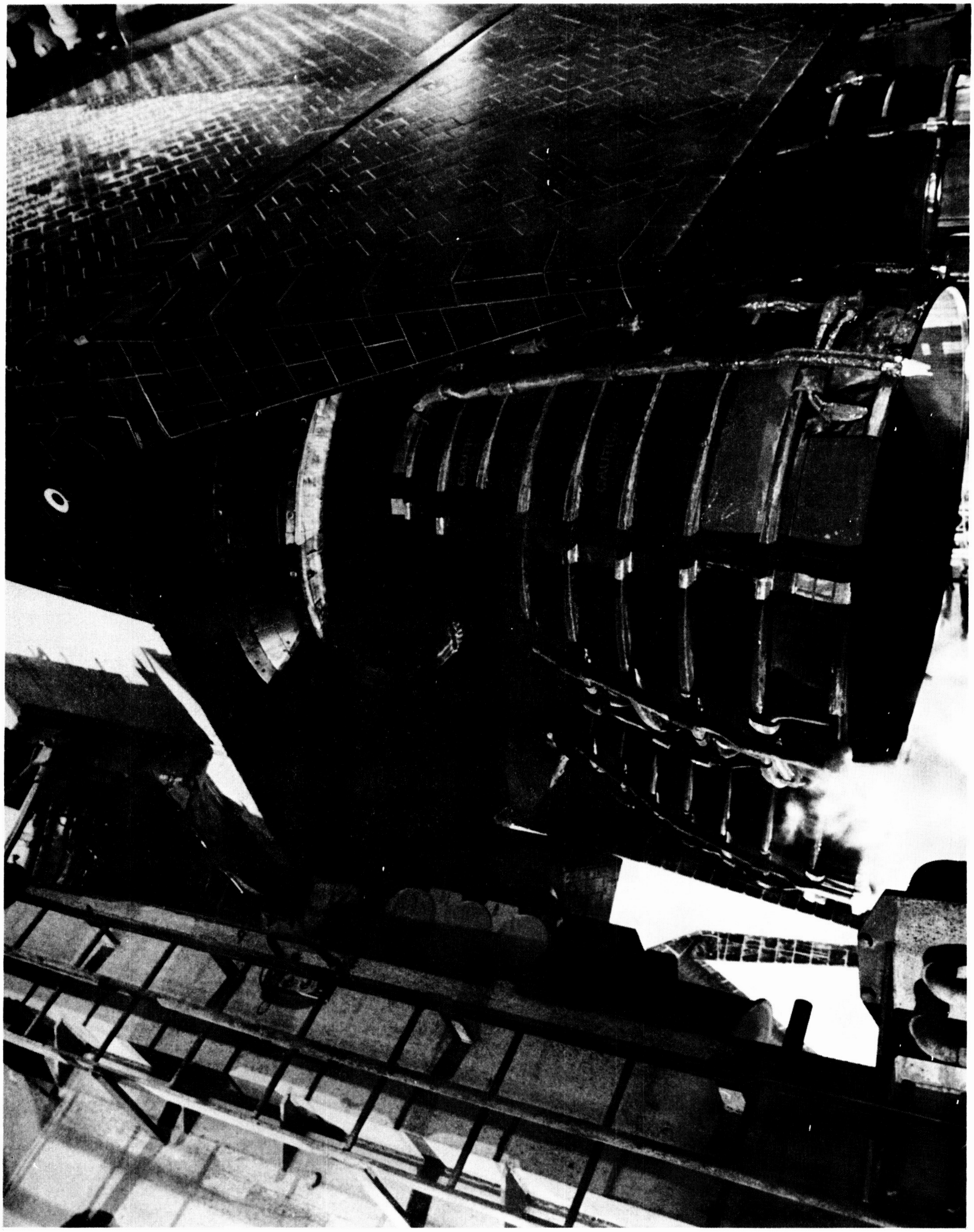
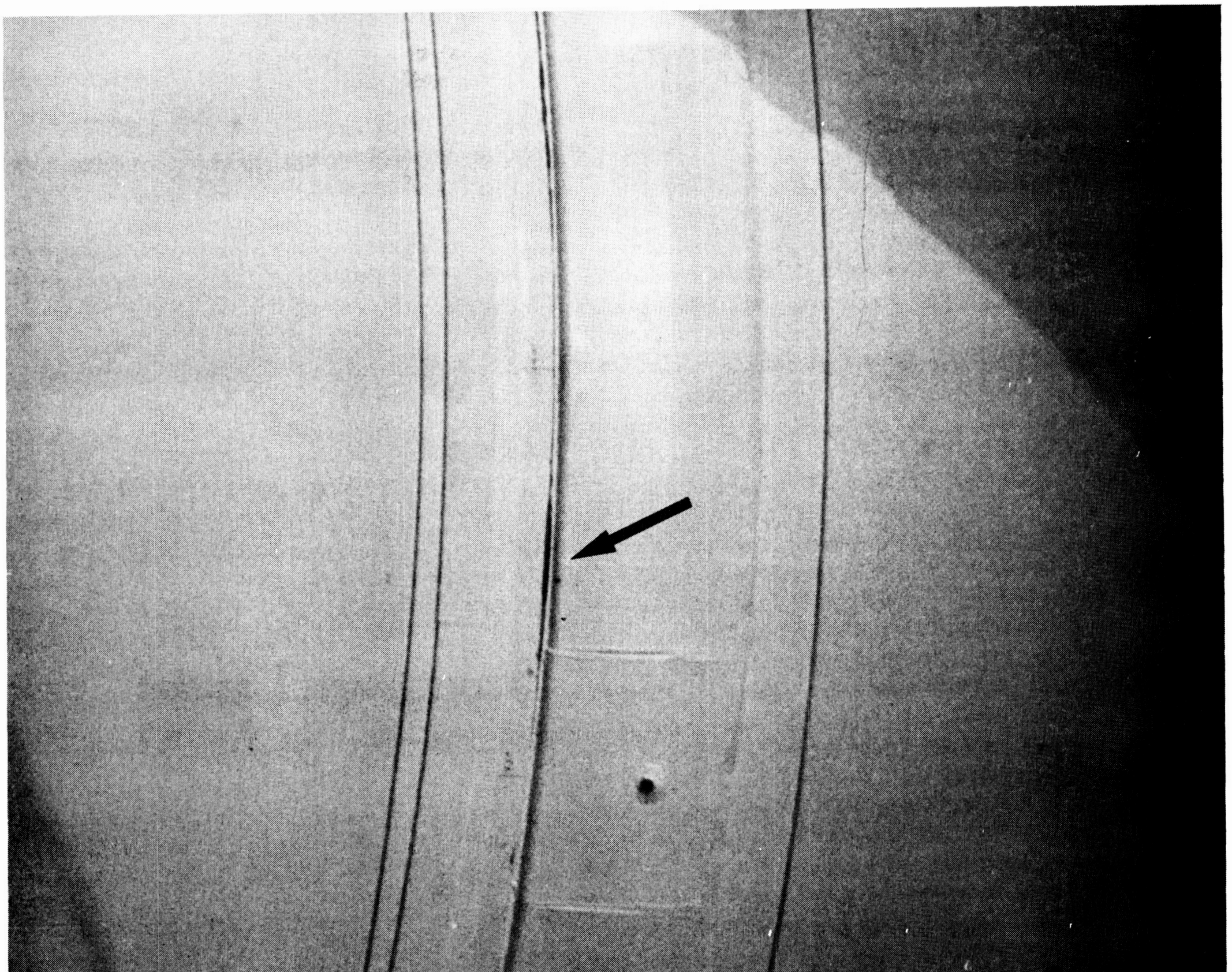
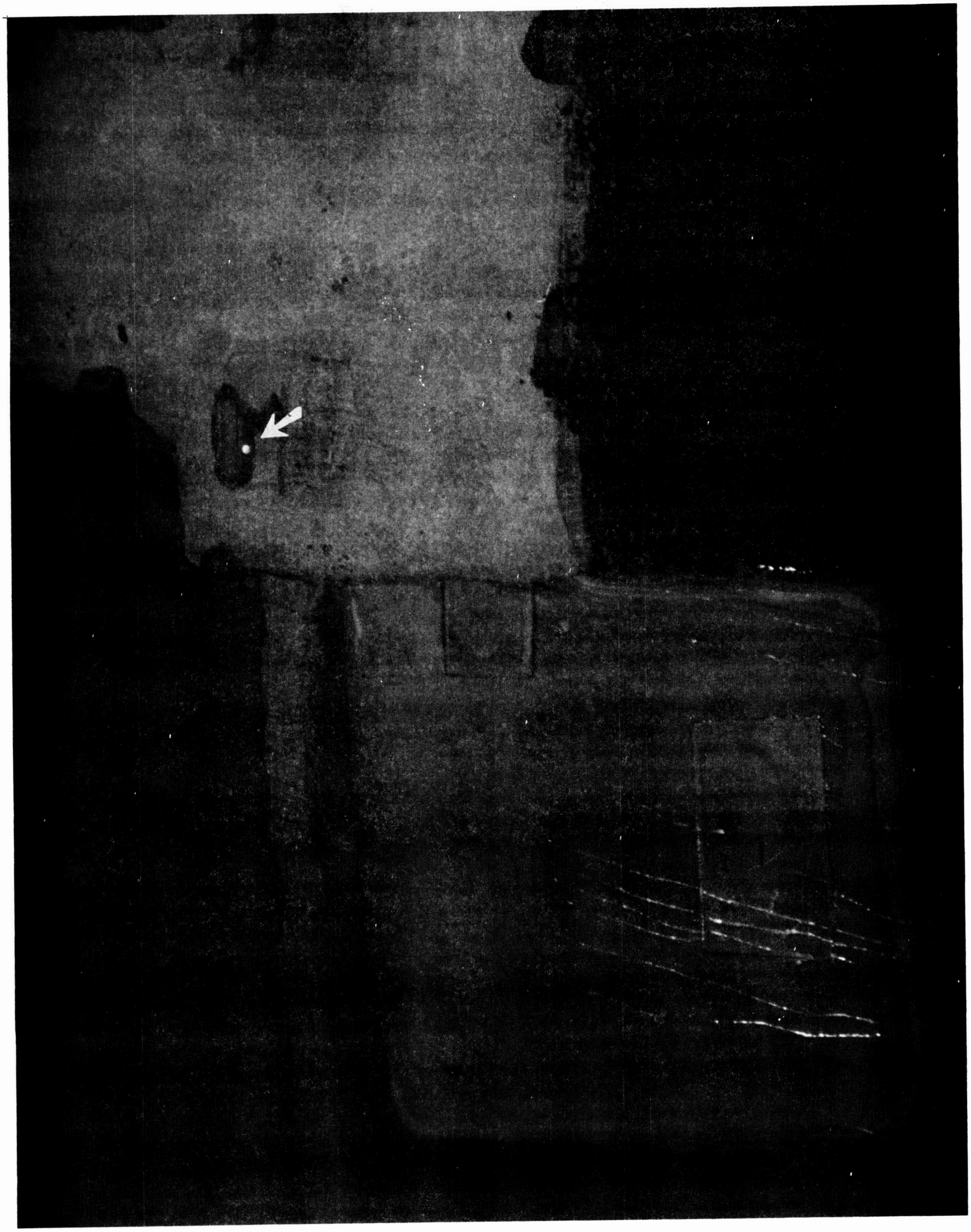


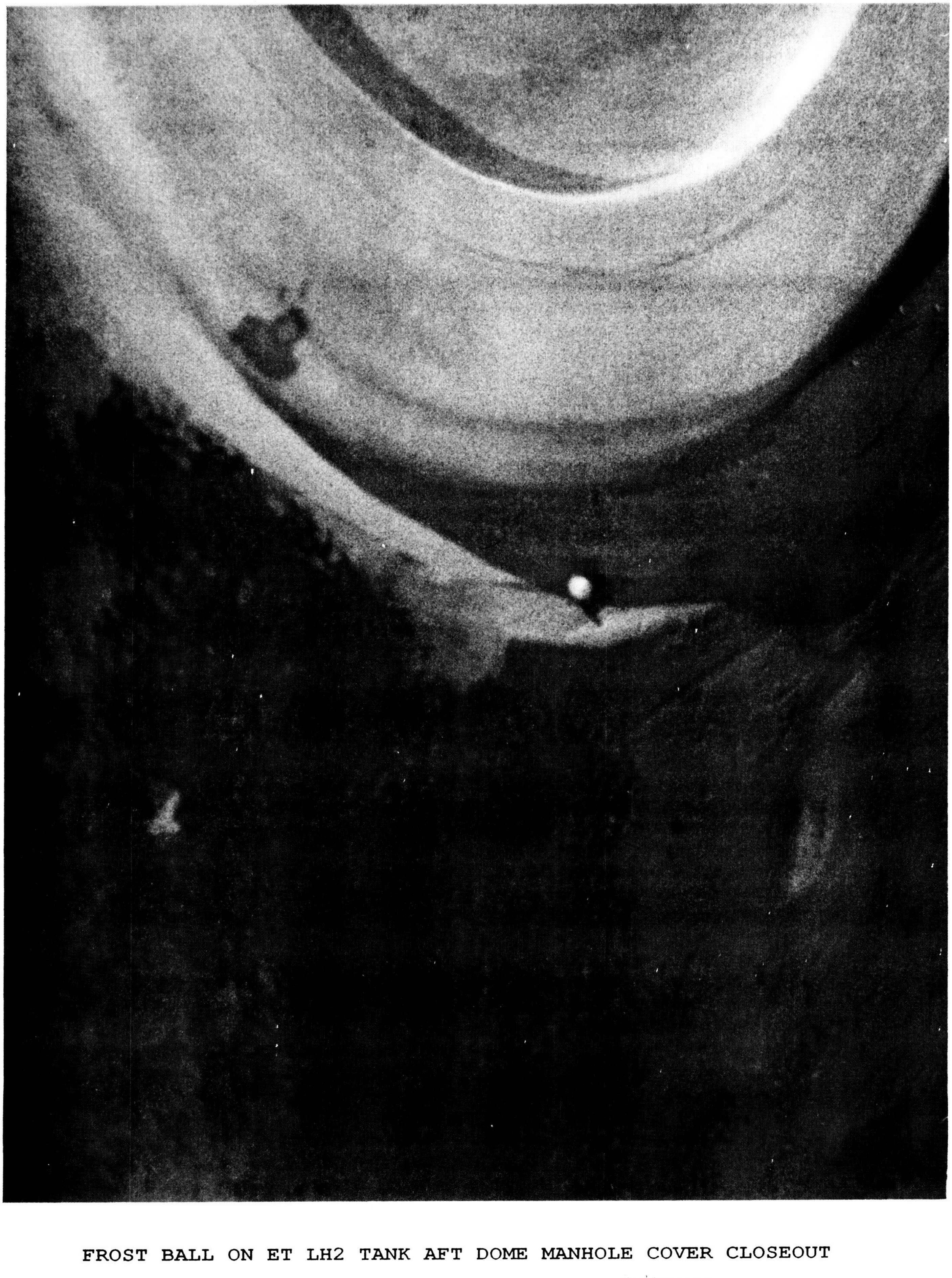
TYPICAL ICE/FROST BUILD-UP ON SSME NOZZLE GOX VENTS.
NO ICE/FROST ON SSME ENGINE MOUNTED HEAT SHIELD



SUSPECT DEBOND OF CLOSEOUT CORK ON LH SRB CENTER FIELD JOINT. DETERMINED TO BE AREA OF MISSING WHITE HYPALON PAINT.



FROST BALL ON ET THIRD (-Z) HARDPOINT CLOSEOUT



FROST BALL ON ET LH2 TANK AFT DOME MANHOLE COVER CLOSEOUT

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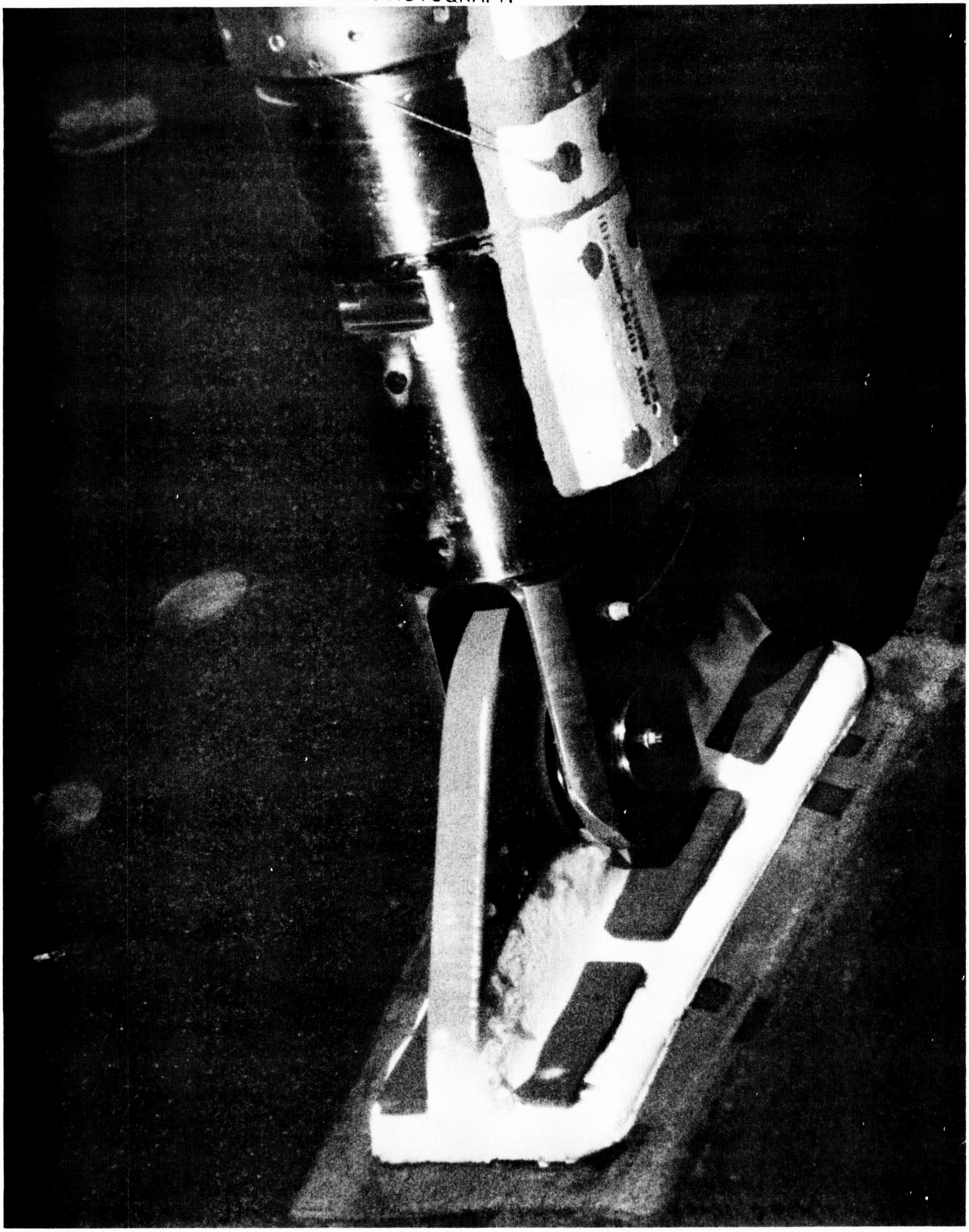
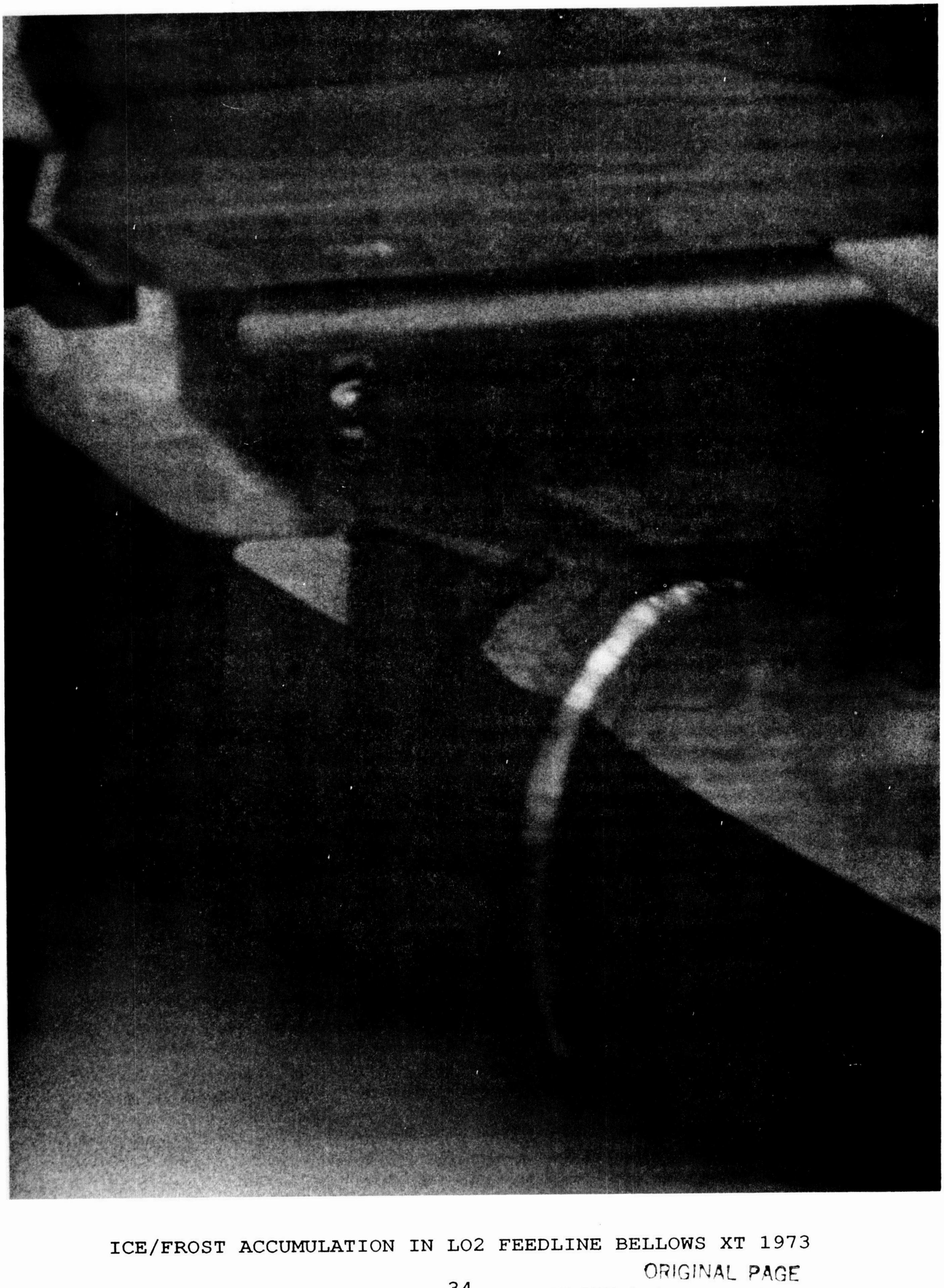


TYPICAL FROST BUILD-UP ON INBOARD SIDE OF -Y ET/SRB AFT STRUT FITTING. CONDENSATE IS PRESENT ON OUTBOARD SIDE OF FITTING.



ICE/FROST ACCUMULATION IN LO2 FEEDLINE BELLOWS XT 1973

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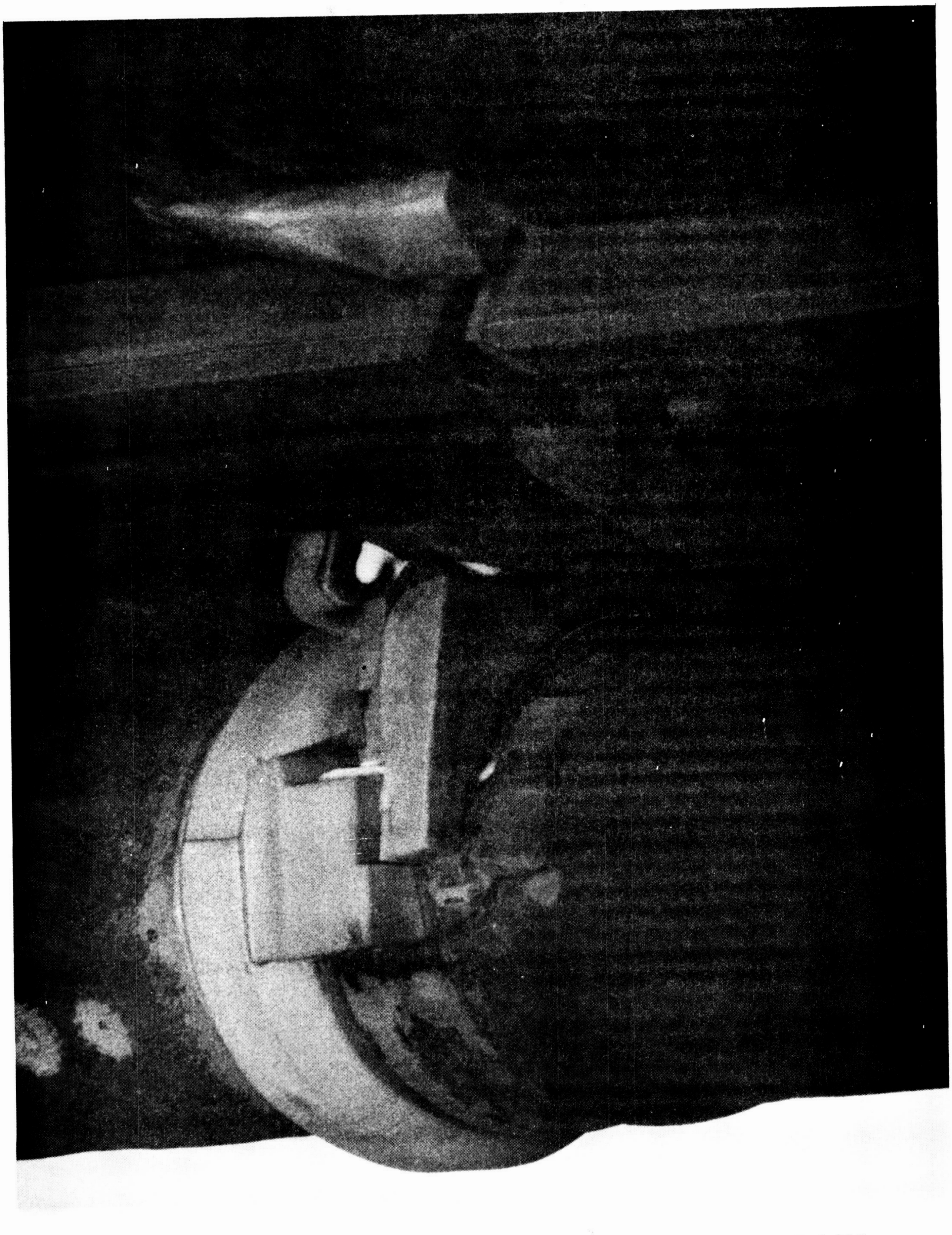

ICE/FROST ACCUMULATION IN LO2 FEEDLINE SUPPORT BRACKET XT 1623

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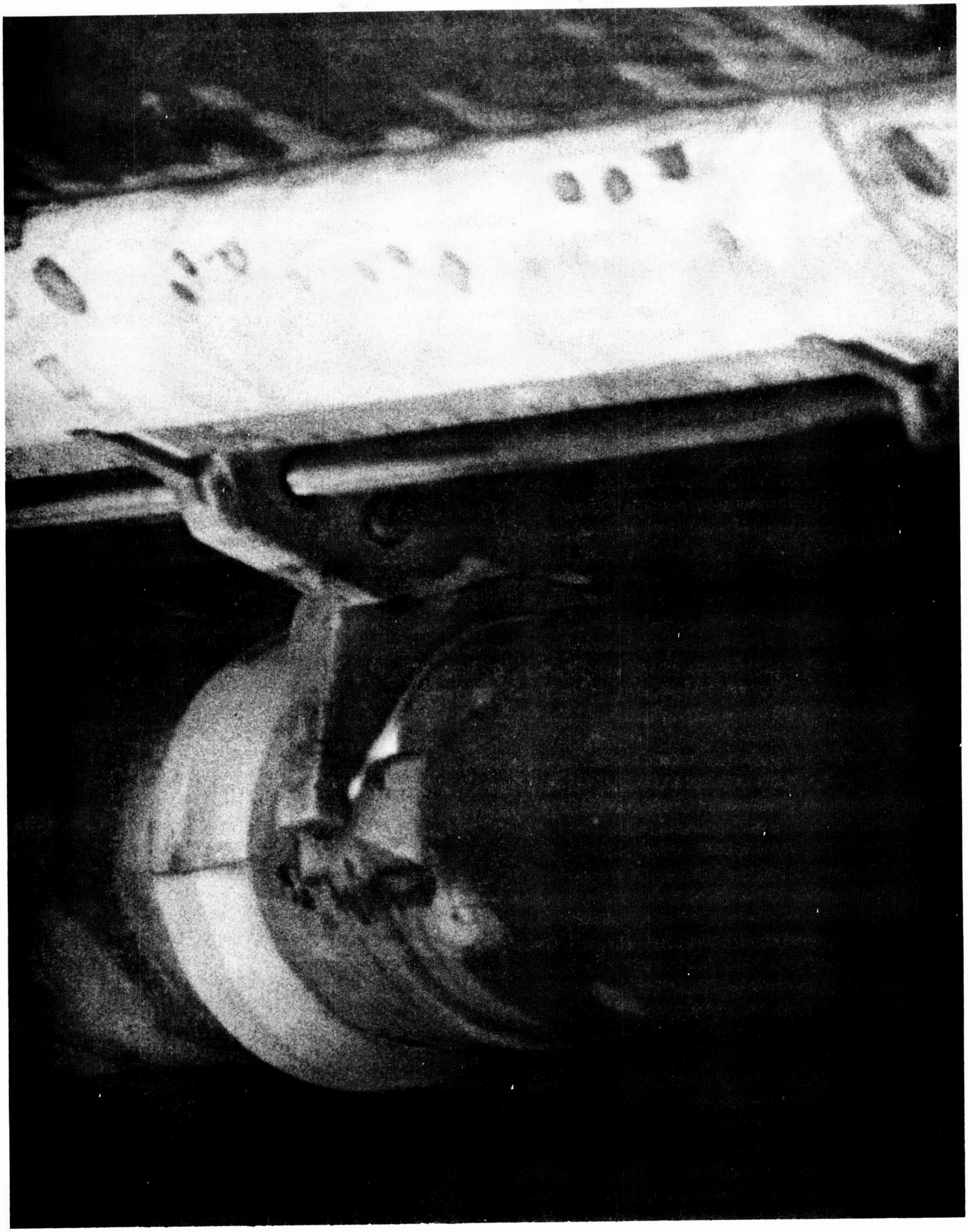

ICE/FROST ACCUMULATION IN LO2 FEEDLINE SUPPORT BRACKET XT 1377

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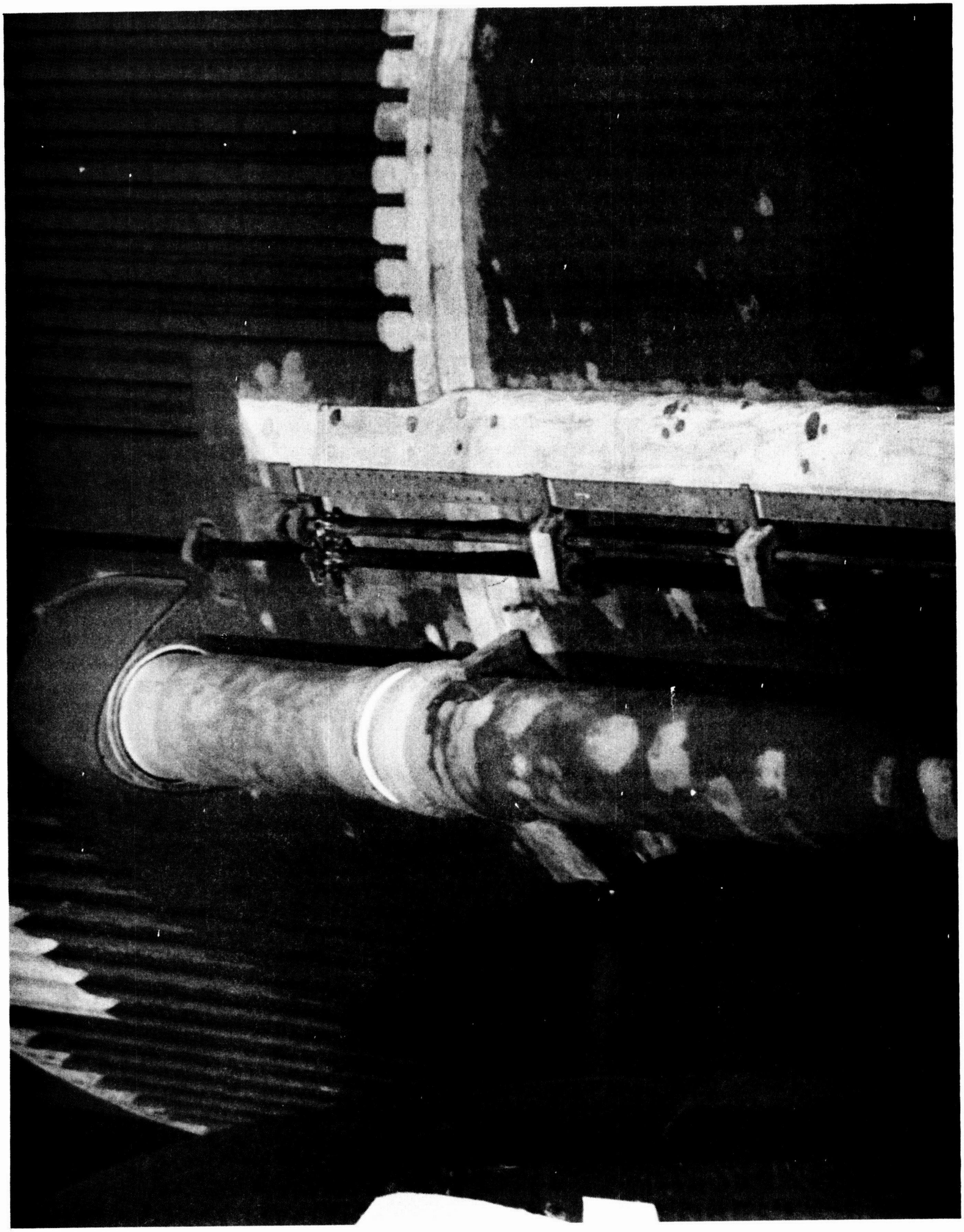

UPPER LO2 FEEDLINE. TYPICAL ICE/FROST ACCUMULATION IS VISIBLE IN FEEDLINE BELLOWS AT XT 1106

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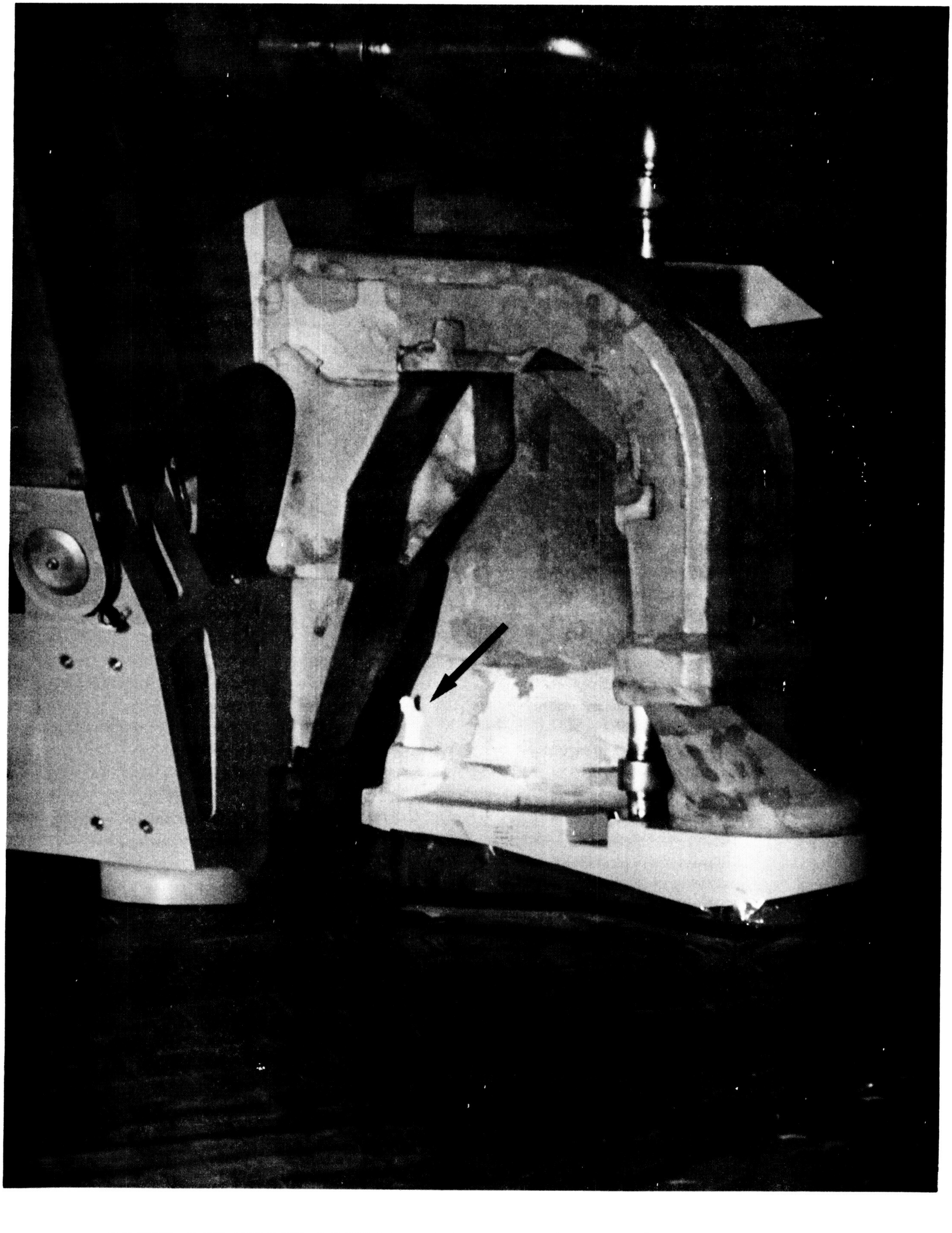
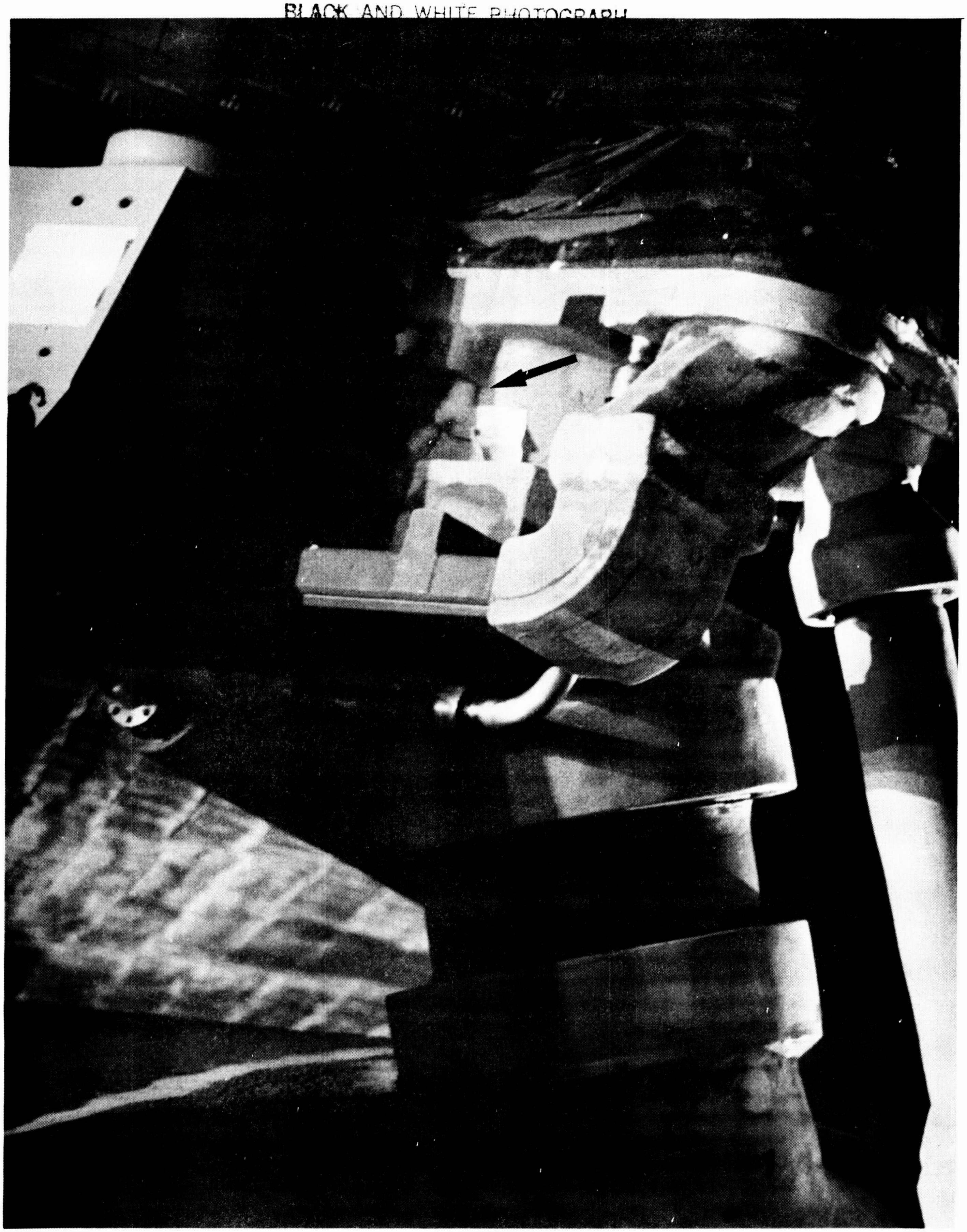
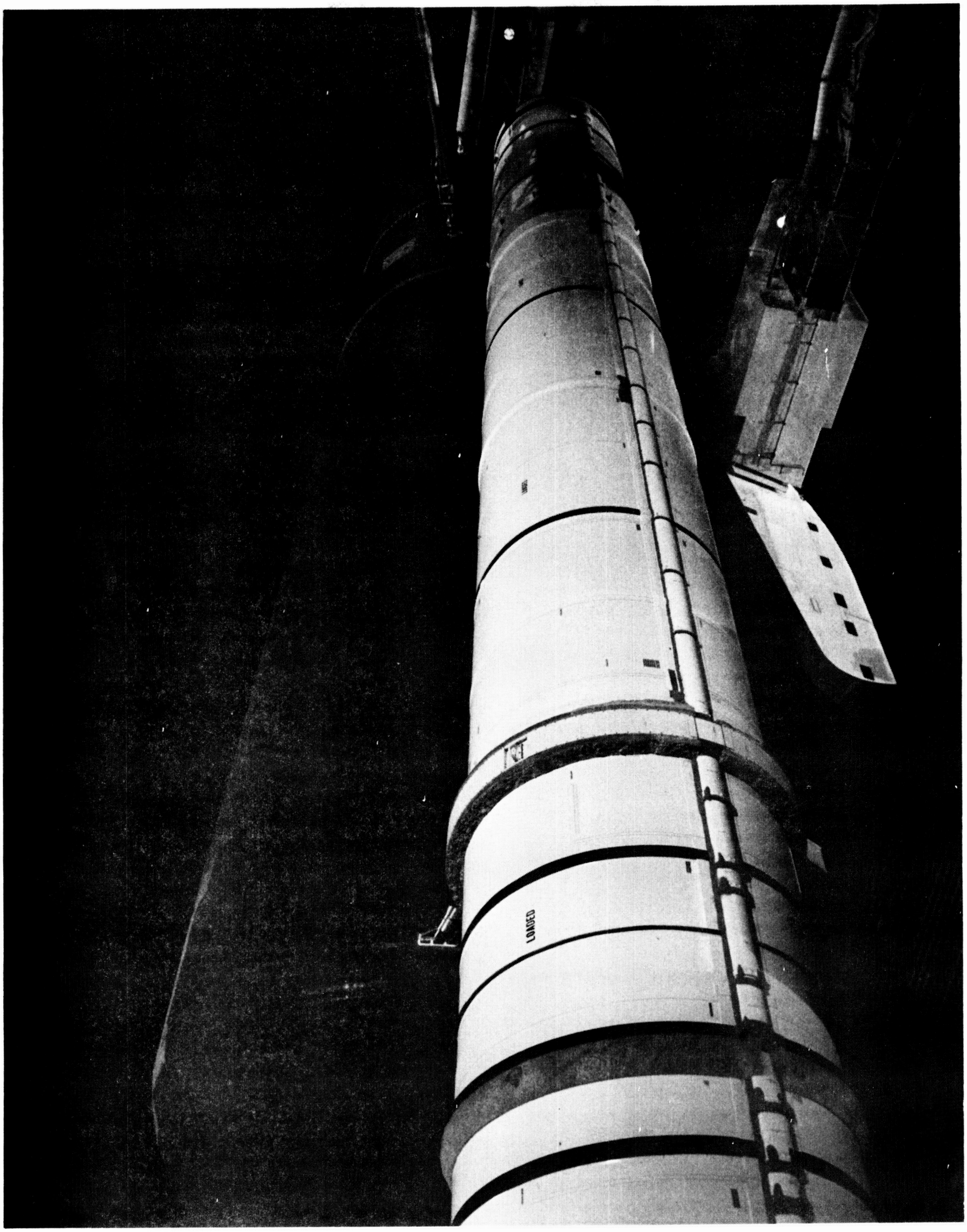


LIGHT ICE/FROST ACCUMULATION ON ET/ORB LO2 UMBILICAL.
TYPICAL FROST FINGER ON PURGE VENT.



LIGHT ICE/FROST ACCUMULATION ON ET/ORB LH2 UMBILICAL. TYPICAL FROST FINGERS HAVE DEVELOPED ON PURGE VENTS.



NO ACREAGE ICE/FROST ON -Z SIDE OF ET LH2 TANK.
NOTE REFLECTION OF CONDENSATE ON LH2 TANK AFT DOME.

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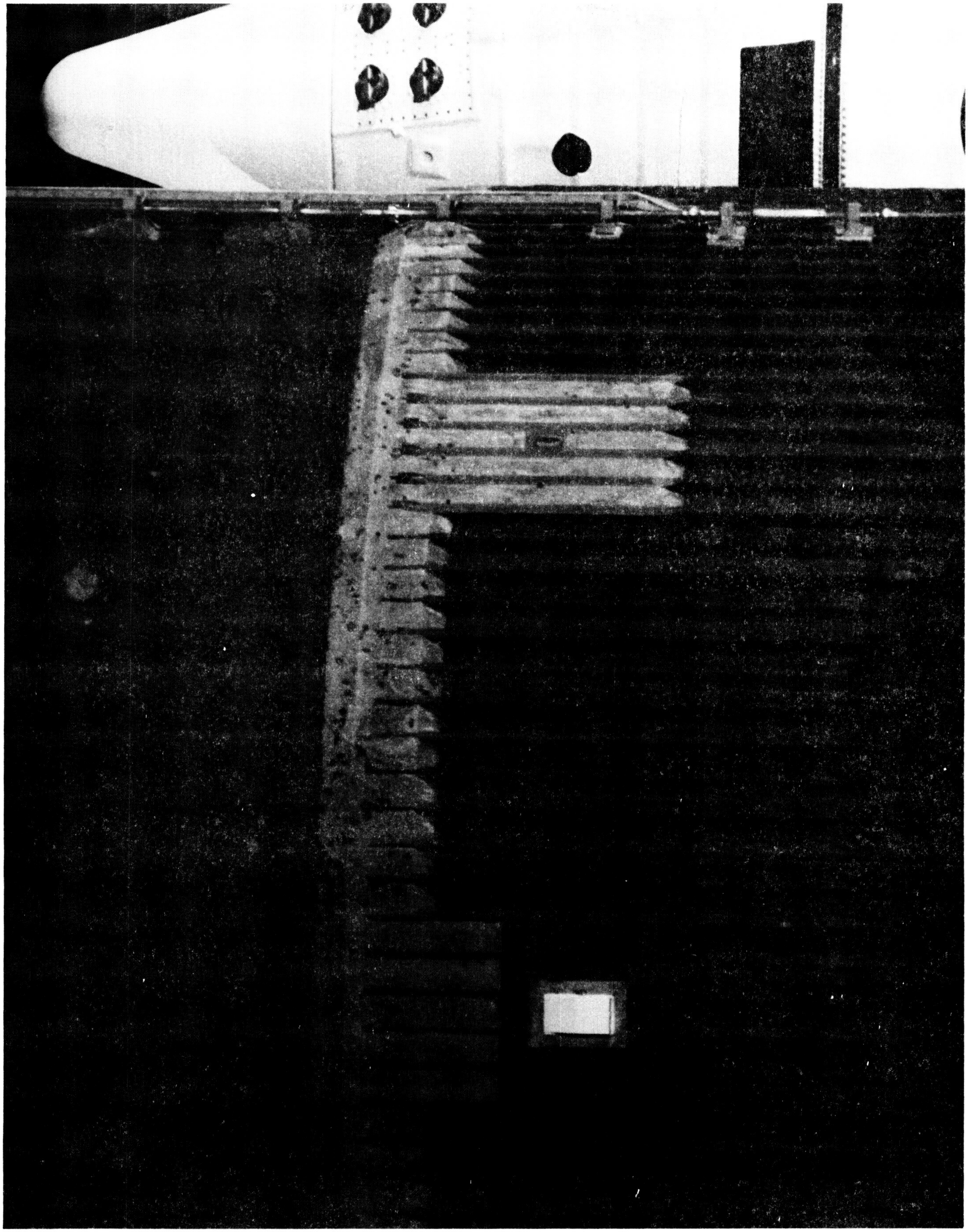

RH SRB NOSECAP AND INTERFACE OF LO2 TANK AND INTERTANK ON +Z SIDE OF VEHICLE. NO ANOMALIES VISIBLE.

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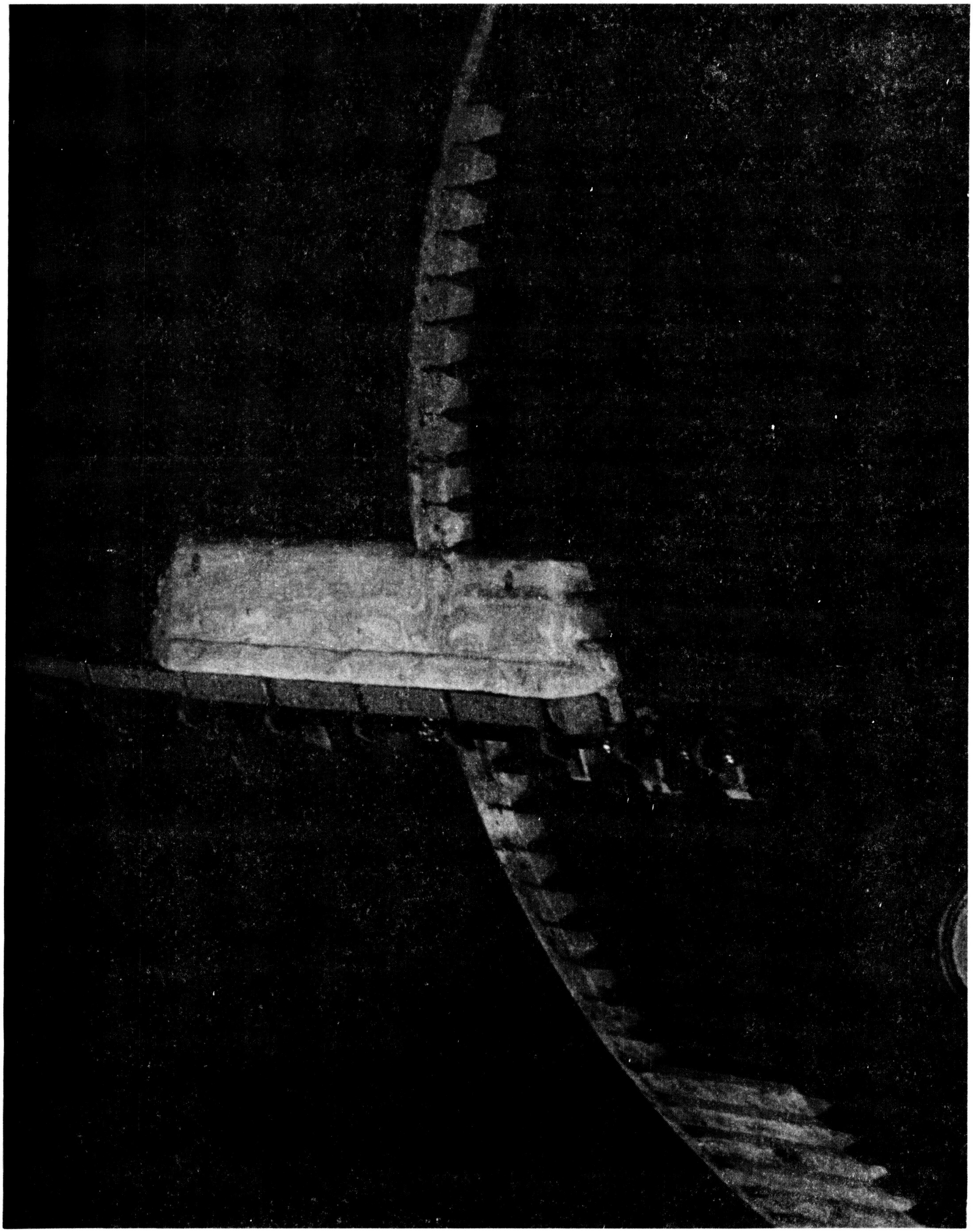

ET LO2 TANK PROTUBERANCE AIR LOAD (PAL) RAMP WITH UNIQUE LONGITUDINAL REPAIR. NO ICE/FROST ON LO2 TANK BARREL SECTION.

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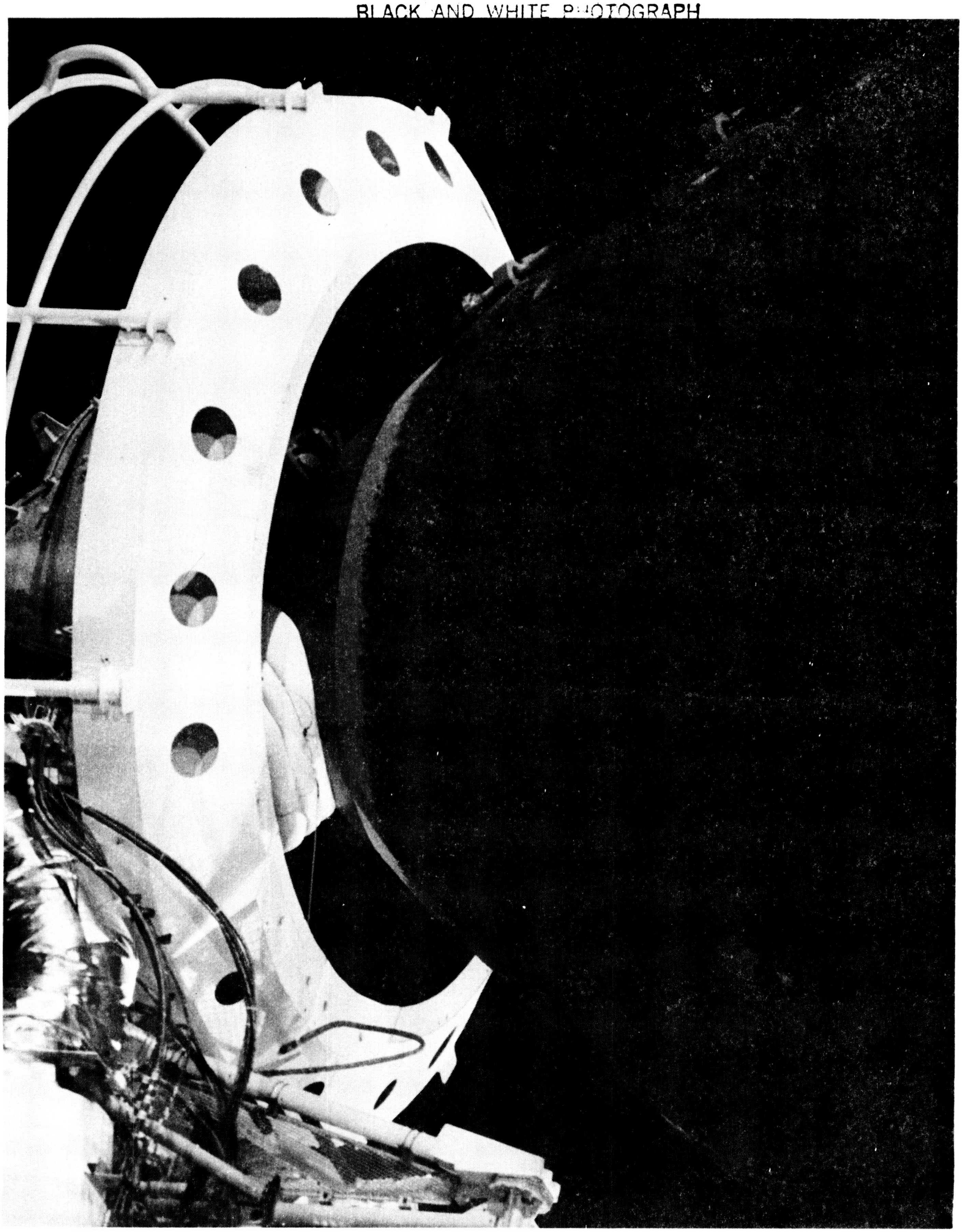


LO2 TANK OGIVE AND GOX VENT HOOD. GOX VENT SEAL IS IN PROPER POSITION, TUMBLE VALVE COVER IS INTACT, NO ICE/FROST ON OGIVE.

FROST FINGERS ON GOX VENT EXHAUST DUCT

4.6 POST DRAIN INSPECTION

The STS-27R launch was scrubbed due to high winds and wind shear aloft. Both the LH2 and LO2 tanks reached 100% fill. A post drain inspection and a tanking inspection of both the vehicle and pad were performed at Pad 39B on December 1, 1988.

No visible TPS damage, such as divots/cracks, was detected by the inspection team on the tank acreage or aft dome.

Some ice remained in the LH2 feedline bellows, LH2 recirculation line bellows, the vertical cable tray vent next to the longeron electrical feed through box, LH2 umbilical vent hole, and on the LH2 umbilical baggies. However, ice accumulation in these areas has occurred previously and is acceptable per NSTS-08303.

The LO2 feedline support bracket areas were still filled with ice. Although a "hands-on" inspection of the feedline could not be conducted due to the 24 hour turnaround, no visible damage around the brackets was observed.

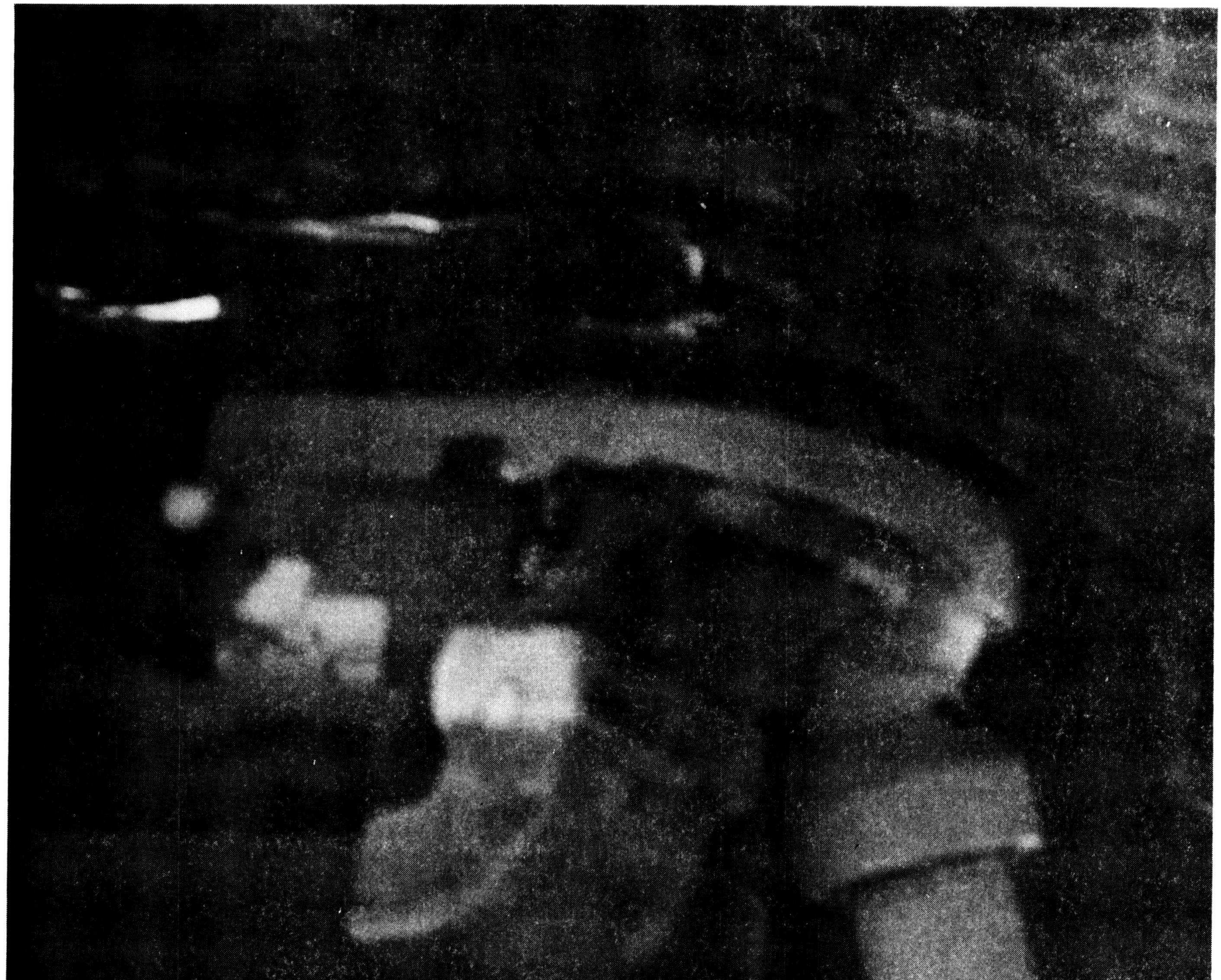
The cable tray and pressurization line barrymount attachment areas were still outgassing, but exhibited no signs of TPS damage.

The tumble valve cover was in good condition and did not not require replacement or waiver. The nosecone and footprint area sustained no TPS damage.

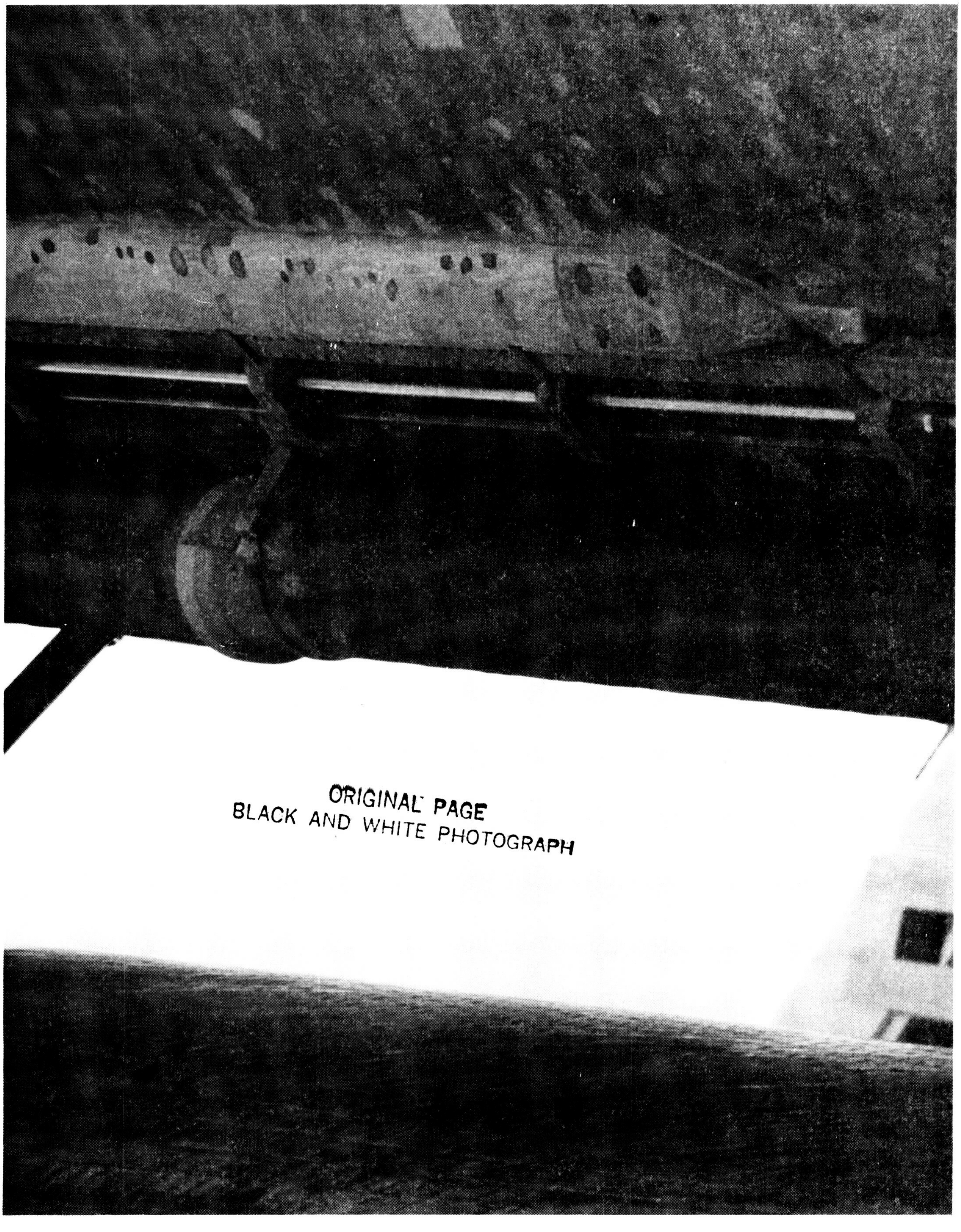
The paper cover on one of the left hand Orbiter reaction control system thrusters was discolored. This discrepancy was documented on PR LP-09-0349. The probable cause for this condition was oxidizer vapor leaking through the thruster valve seat.

No SRB anomalies were visible to the inspection team.

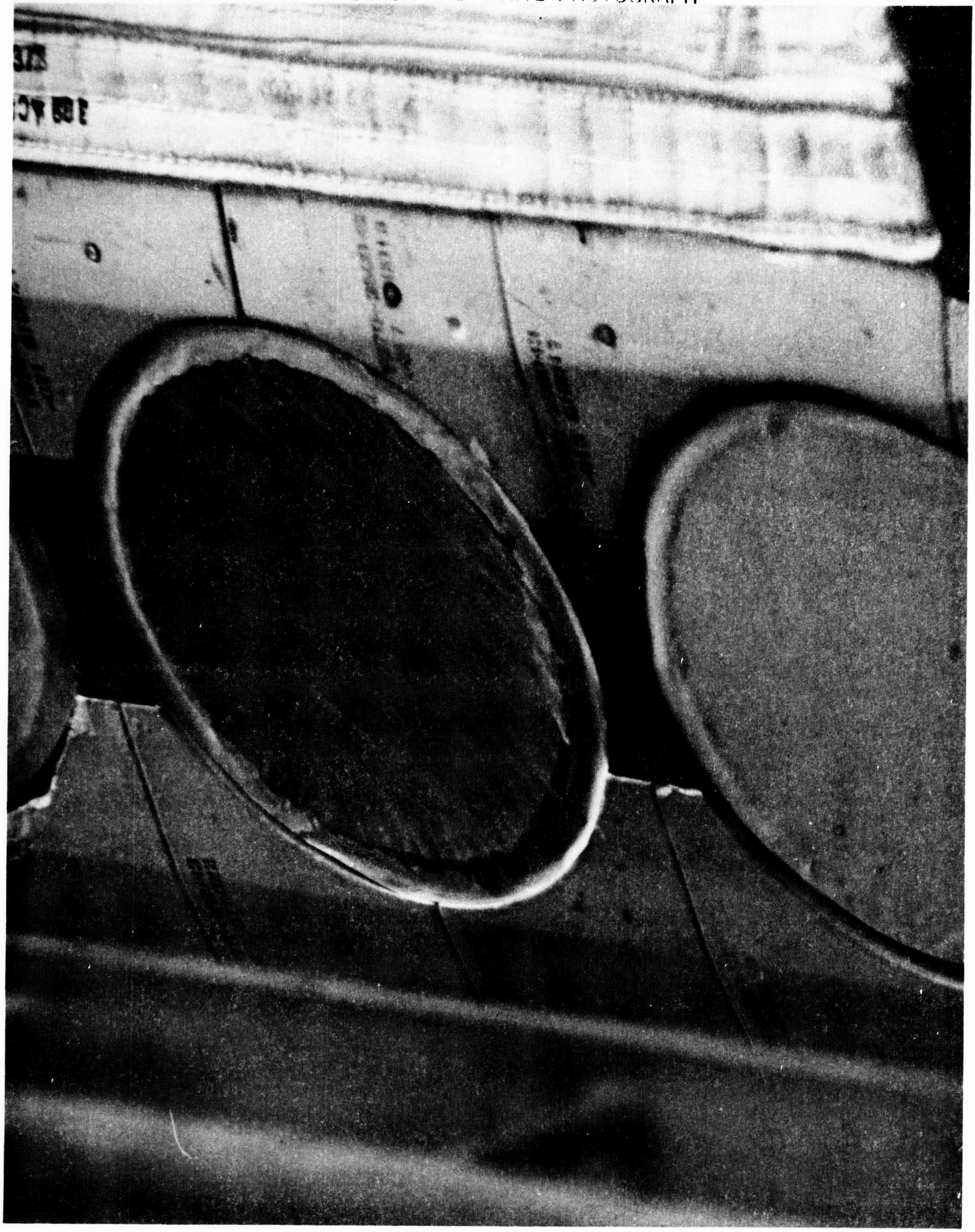
Overall, the External Tank was in generally good condition and was ready to support another cryo loading. Likewise, the Orbiter, SRBs, and pad facilities were found to be in good condition and ready to support another launch attempt.



ICE/FROST STILL PRESENT ON ET/ORB LH2 UMBILICAL AFTER DRAIN



SOME ICE/FROST STILL PRESENT IN LO2 FEEDLINE SUPPORT BRACKET AFTER DRAIN. NO VISIBLE TPS DAMAGE.



DISCOLORED RCS THRUSTER BUTCHER PAPER
COVER ON -Y SIDE OF LH OMS POD STINGER

5.0 LAUNCH

STS-27R was successfully launched at 0931 2 December 1988.

5.1 ICE/FROST INSPECTION

The Ice/Frost Inspection of the cryoloaded vehicle was performed on 2 December 1988 from 0413 to 0545 hours during the two hour built-in-hold at T-3 hours in the countdown. There were no violations of NSTS-08303 or Launch Commit Criteria. Ambient weather conditions at the time of the inspection were:

Temperature:	54 F
Relative Humidity:	49 %
Wind Speed:	12 Knots
Wind Direction:	330 Degrees

The STI portable infrared scanner again accompanied the Ice Team during the Ice/Frost Inspection. Figures 6 and 7 present a summary of the vehicle surface temperature measurements taken with this device.

5.2 ORBITER OBSERVATIONS

No Orbiter tile anomalies were observed. The average Orbiter surface temperature ranged from 48 to 54 degrees F. The surface temperatures of the SSME engine mounted heat shields were recorded as 16 degrees F for SSME #1, 17 degrees F for SSME #2, and 34 degrees F for SSME #3. Some frost was present at the engine to heat shield interface of SSME #1 and SSME #2.

5.3 SRB OBSERVATIONS

No SRB anomalies were observed. The STI portable infrared scanner recorded LH SRB surface temperatures between 53 and 56 degrees F while temperatures on the RH SRB ranged from 49 to 54 degrees F. An average temperature of 66 degrees F was recorded for the SRB field joints. The predicted Propellant Mean Bulk Temperature (PMBT) supplied by MTI was 69 degrees F.

5.4 EXTERNAL TANK OBSERVATIONS

No acreage icing or condensate was visible on the LO2 tank. Light frost was noted on a 1" plug pull repair on the +Z side of the LO2 tank barrel 4 feet forward of the Intertank flange at approximately Xt 800. The LO2 tank PAL ramp had frost at the ramp to acreage interface. Both of these conditions are acceptable per NSTS-08303. The IR scanner showed a surface temperature range of 46 to 51 degrees F on the LO2 tank.

FIGURE 6. INFRA-RED SCANNER SSV SUMMARY DATA

NOTE: All surface temperature measurements were taken with emittance = 1.0 and are in degrees F.

TIME: 0413 - 0545 EST
DATE: 12/2/88
VEH. STS- 27R

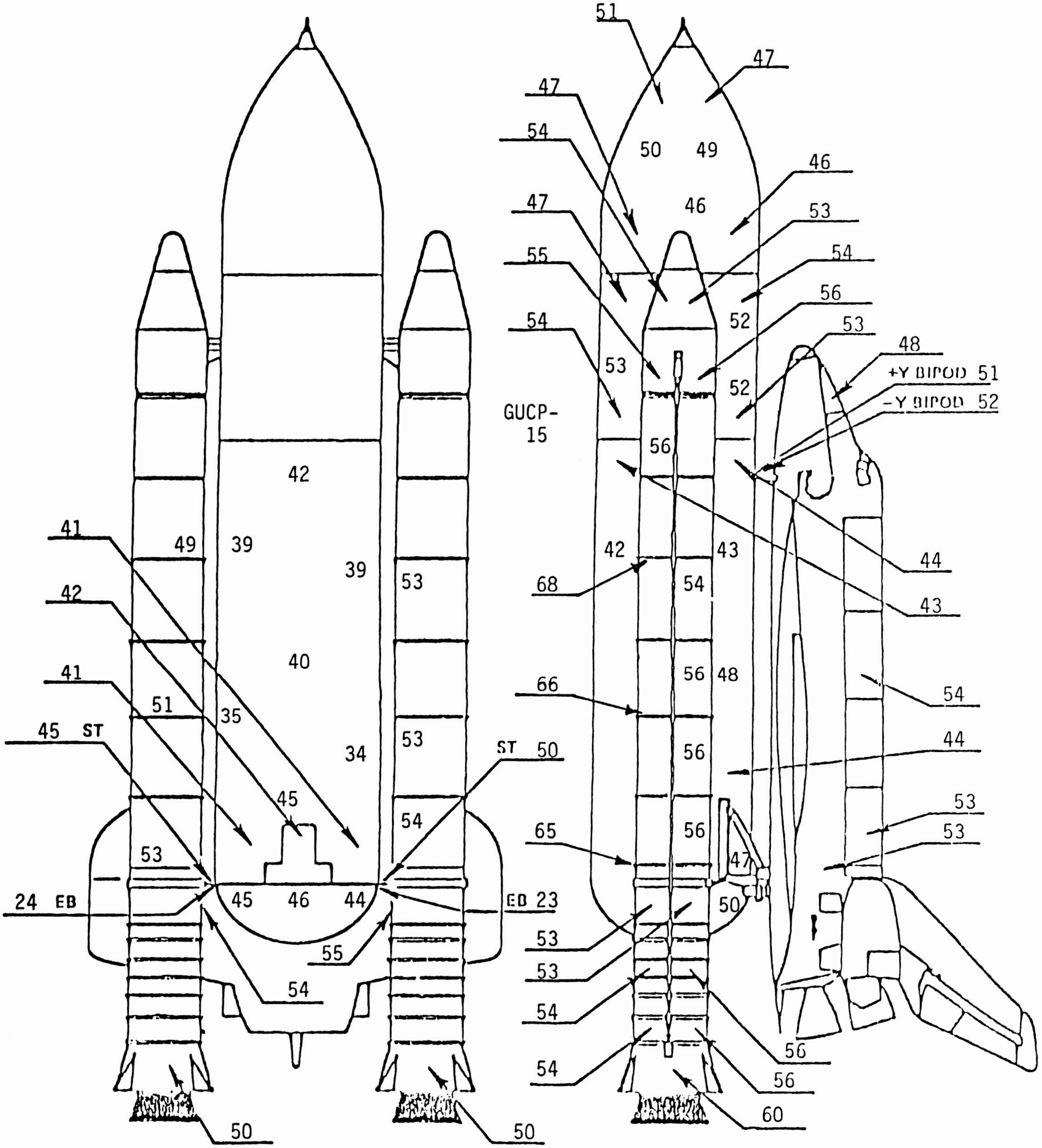


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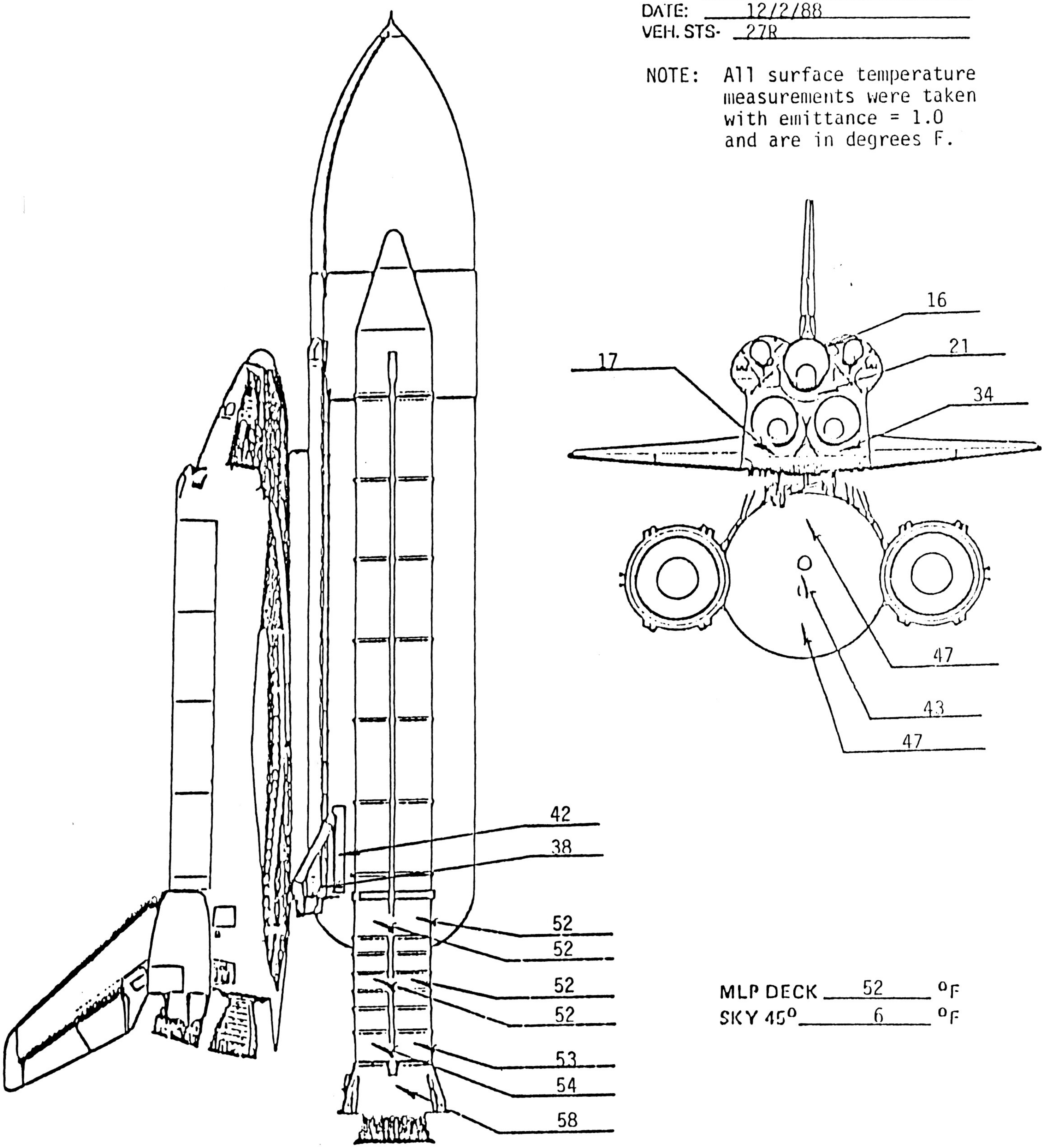
FIGURE 7 INFRA-RED SCANNER SSV SUMMARY DATA

TIME: 0413 - 0545 EST
DATE: 12/2/88
VEH. STS- 27R

NOTE: All surface temperature measurements were taken with emittance = 1.0 and are in degrees F.



MLP DECK 52 °F
SKY 45° 6 °F

No condensate was visible on the Intertank. Some -Z stringer root frost was noted at the LH2 and LO2 tank flanges. The average temperature of the Intertank was recorded as 52 degrees F.

No acreage icing was observed on the LH2 tank. A small amount of condensate was present on the upper barrel and light acreage frost was present in areas on the -Z side of the LH2 tank. Surface temperatures measured by the IR scanner ranged from 35 to 48 degrees F. Frost was present in 4 areas on the -Z third hardpoint closeout, in 3 areas on the +Y longeron closeout, in 3 spots on the aft dome, and on an acreage repair 4 feet above the +Y longeron at approximately Xt 1900. All of these frost areas were small and are acceptable per NSTS-08303. The +Y thrust strut had a crack in the crotch area which exhibited some frost. The LH2 PAL and Ice/Frost ramps had frost at the ramp to acreage interface. Both of these conditions are also acceptable per NSTS-08303.

Ice/Frost covered the lower EB fittings outboard to the strut pin hole. No condensate was present on the rest of the fitting and the struts were dry.

Normal icing conditions were observed on the LO2 feedline support brackets. Ice/frost was also present on all the LO2 feedline bellows.

The LO2 ET/ORB umbilical was free of ice except for a small area of frost on the umbilical baggie 2 o'clock position and frost fingers on the purge vents. Ice/frost had formed in the LH2 ET/ORB umbilical recirculation line bellows, purge vents, cavities, and in an area on the aft side of the umbilical baggie.

No ice was present on the ET nosecone and its surface temperature was recorded by the IR scanner as 51 degrees F. The tumble valve cover was intact and not protruding.

The launch summary of ice/frost console observation anomalies consists of 9 items. Anomaly sequential numbering continues from the initial cryo loading during the launch scrub.

Anomaly 009 documented a crack in the +Y thrust strut crotch area TPS. Light frost was present in the crack and on the knuckle, but was acceptable per NSTS-08303.

Vapors emanating from the GUCP purge vent cavity was recorded on Anomaly 010. This item is not a debris issue (reference Anomaly 004).

Frost accumulated in the +Y vertical strut cable tray vent gap, station XT-2058, to the right of the electrical feedthrough box (Anomaly 011). This is acceptable per the NSTS-08303 criteria.

Anomaly 012 documented a frost accumulation on the LO2 feedline support brackets at stations XT-1360, 1623, and 1851. None of these violate the ice/frost/ debris criteria.

Ice/frost on the ET/ORB LO2 umbilical purge vents and on the baggie were recorded on Anomaly 013 and are acceptable.

Frost formed on four areas of the aft hardpoint closeout pads (Anomaly 014), but this area is not an ice debris concern.

Anomaly 015 documented a frost line, which is acceptable per NSTS-08303, between the -Z LH2 manhole cover closeout and the aft dome acreage.

Ice/frost accumulation on the ET/ORB LH2 baggie and purge vents was recorded as an acceptable condition on Anomaly 016.

Ice/frost lines had formed along all ramps on the LH2 tank between stations XT-1120 through 1787. The NSTS-08303 ice/frost criteria allows this formation for flight.

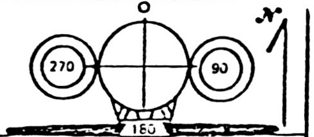
The ice prediction computer program was run from 2245 to 0930 hours and the results are tabulated in Figures 8, 9, and 10.

5.5 FACILITY OBSERVATIONS

All debris concerns previously identified had been resolved prior to cryoloading and no new items were noted. No leaks were observed on either LO2 or LH2 TSM T-0 umbilical. The modification to the GH2 vent line prevented any ice from forming but some frost, which was expected, had accumulated on the GUCP. Visual and infrared observations of the GOX seals confirmed no leakage. Small frost fingers had formed on the GOX vent ducts.

STS-27R	TEST: S0007, LAUNCH	DATE: 12/02/88	T-0 TIME: 0931 DATE: 12/02/88

ORBITER	ET	SRB	MLP	PAD	LO2	LH2
OV-104	23	BI030	1	39B	CHILLDOWN TIME: 2246 SLOW FILL TIME: 2300 FAST FILL TIME: 0201 REPLENISH TIME: 0409	CHILLDOWN TIME: 2246 SLOW FILL TIME: 2256 FAST FILL TIME: 2325 REPLENISH TIME 0220



LOCAL TIME	CONDITIONS					LO_2 TANK STA 370 TO 540					LO_2 TANK STA 550 TO 852					LH_2 TANK STA 1130 TO 1380					LH_2 TANK STA 1380 TO 2058				
	TEMP. °F	REL HUM. %	DEW PT °F	WIND VEL KNTS	WIND DIR DEG	REGION	LOCAL VEL KNTS	SOFI TEMP °F	COND RATE IN/HR	ICE RATE IN/HR	REGION	LOCAL VEL KNTS	SOFI TEMP °F	COND RATE IN/HR	ICE RATE IN/HR	REGION	LOCAL VEL KNTS	SOFI TEMP °F	COND RATE IN/HR	ICE RATE IN/HR	REGION	LOCAL VEL KNTS	SOFI TEMP °F	COND RATE IN/HR	ICE RATE IN/HR
2245	56.6	48	36.77	10	329		5,90	41.18	0	-.0423		5.90	35.01	.0004	-.0166		4.6	32.03	+.0009	0.000		12.3	41.5	0	-.0728
2300	56.4	46.8	35.91	8	319		4.72	38.96	0	-.0284		4.72	32.63	.0006	-.0030		3.68	29.43	.0010	+.0116		9.84	38.86	0	-.0460
2315	56.2	47.6	36.17	5	327		2.95	35.00	.0001	-.0107		2.95	28.30	.0010	+.0143		2.30	24.09	.0011	+.0254		6.15	34.04	.0005	-.0118
2330	55.8	49	36.55	9	329		5.31	39.5	0	-.0335		5.31	33.53	.0006	-.0080		4.14	30.49	.0010	+.0078		11.07	39.63	0	-.0565
2345	54.2	48.6	34.79	10	319		5.90	38.82	.000	-.0301		5.90	32.84	+.0005	-.0047		4.60	29.90	.0009	+.0109		12.3	39.21	0	-.0524
0000	53.8	47.8	33.97	9	304		5.31	37.46	0	-.0222		5.31	31.55	.0005	+.0030		4.14	28.31	.0010	+.0171		11.07	37.61	0	-.0378
0015	53.6	46.8	33.33	8	303		4.72	36.16	0	-.0155		4.72	30.15	0006	+.0095		3.68	26.67	+.0010	+.0223		9.84	36.17	0	-.0251
0030	53.8	45.4	32.84	10	306		5.90	38.32	0	-.0244		5.90	31.91	0002	+.0008		4.60	28.87	.0007	+.0154		12.3	38.78	0	-.0426
0045	53	47	32.96	9	304		5.31	36.65	0	-.0175		5.31	30.66	0005	+.0075		4.14	27.38	.0009	.0209		11.07	36.91	0	-.0299
0100	53.2	47	33.11	9	310		5.31	36.84	0	-.0185		5.31	30.84	.0005	+.0066		4.14	27.57	.0009	+.0201		11.07	37.10	0	-.0315
0115	53.4	47.4	33.44	9	315		5.31	37.05	0	-.0198		5.31	31.10	.0005	+.0053		4.14	27.84	.0009	+.0190		11.07	37.3	0	-.0338
0130	53.4	48.8	34.13	10	316		5.90	38.04	0	-.0260		5.90	32.14	.0005	-.0008		4.6	29.17	+.0009	+.0142		12.3	38.44	0	-.0457
0145	53	48.4	33.58	9	308		5.31	36.69	0	-.0189		5.31	30.94	.0006	+.0062		4.14	27.65	.0010	+.0199		11.07	36.93	0	-.0324
0200	53.2	48.6	33.83	7	316		4.13	34.62	0	-.0106		4.13	28.91	.0008	+.0144		3.22	25.15	+.0011	+.0263		8.61	34.26	0	-.0157
0215	53.2	50.8	35.00	6	320		3.54	33.81	.0002	-.0074		3.54	27.84	.0010	+.0175		2.76	23.78	.0012	+.0288		7.38	33.35	.0005	-.0090

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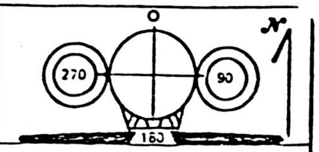
FIGURE 8. Ice/Frost Computer Predictions

STS-27R	TEST: S0007, LAUNCH				DATE: 12/02/88	T-0 TIME: 0931 DATE: 12/02/88
ORBITER OV-104	ET 23	SRB BI030	MLP 1	PAD 39B	LO₂ CHILLDOWN TIME: 2246 FAST FILL TIME: 0201 SLOW FILL TIME: 2300 REPLENISH TIME: 0409	LH₂ CHILLDOWN TIME: 2246 FAST FILL TIME: 2325 SLOW FILL TIME: 2256 REPLENISH TIME 0220



LOCAL TIME	CONDITIONS					LO₂ TANK STA 370 TO 540					LO₂ TANK STA 550 TO 852					LH₂ TANK STA 1130 TO 1380					LH₂ TANK STA 1380 TO 2058				
	TEMP. °F	REL HUM. %	DEW PT °F	WIND VEL KNTS	WIND DIR DEG	REGION	LOCAL VEL KNTS	SOFI TEMP °F	COND RATE IN/HR	ICE RATE IN/HR	REGION	LOCAL VEL KNTS	SOFI TEMP °F	COND RATE IN/HR	ICE RATE IN/HR	REGION	LOCAL VEL KNTS	SOFI TEMP °F	COND RATE IN/HR	ICE RATE IN/HR	REGION	LOCAL VEL KNTS	SOFI TEMP °F	COND RATE IN/HR	ICE RATE IN/HR
0230	54.6	31.6	36.76	7	333		4.13	36.36	.0001	-.0192		4.13	30.88	.001	+.0061		3.22	27.17	.0013	+.0193		8.61	36.08	.0002	-.0296
0245	54.2	52.6	36.88	10	323		5.90	38.97	0	-.0346		5.90	33.6	+.0007	-.0090		4.6	30.7	.0012	+.0074		12.3	39.25	0	-.0603
0300	53.8	54	37.19	10	329		5.9	38.61	0	-.0340		5.9	33.49	+.0008	-.0084		4.6	30.59	.0012	+.0081		12.3	38.89	0	-.0594
0315	53	54.2	36.52	7	313		4.13	35.26	.0002	-.0144		4.13	29.83	+.0011	+.0108		3.22	26.03	+.0014	+.0235		8.61	35.03	.0005	-.0222
0330	52.4	54.8	36.23	9	318		5.31	36.34	0	-.0223		5.31	31.63	+.0010	+.0031		4.14	28.3	+.0013	+.0175		11.07	36.44	0	-.0384
0345	52.8	52.6	35.53	10	316		5.9	37.58	0	-.0270		5.90	32.3	+.0008	-.0016		4.6	29.34	+.0012	+.0137		12.3	37.91	0	-.0476
0400	52.6	51.8	34.93	9	327		5.31	36.43	0	-.0203		5.31	31.24	+.0008	+.0049		4.14	27.92	.0012	+.0189		11.07	36.59	0	-.0350
0415	55.6	50.6	37.21	12	327		7.08	41.82	0	-.0513		7.08	36.04	.0003	-.0254		5.52	33.12	.0009	-.0060		14.76	42.39	000	-.0816
0430	55.8	48.6	36.33	15	335		8.85	43.73	0	-.0663		8.85	38.08	0	-.0452		6.9	34.87	.0004	-.0177		18.45	44.55	0	-.1216
0445	55.2	48	35.43	15	337		8.85	43.12	0	-.0610		8.85	37.5	0	-.0351		6.9	34.16	.0003	-.0134		18.45	43.97	0	-.1122
0500	55.2	48	35.43	14	332		8.26	42.59	0	-.0558		8.26	36.71	0	-.0299		6.44	33.57	.0004	-.0094		17.22	43.38	0	-.1019
0515	53.4	50.2	34.88	11	330		6.49	38.89	0	-.0324		6.49	33.17	.0004	-.007		5.06	30.36	+.0009	+.0093		13.53	39.41	0	-.0580
0530	52.6	49.2	33.61	9	313		5.31	36.33	0	-.0178		5.31	30.72	+.0006	+.0074		4.14	27.42	+.0010	+.0209		11.07	36.56	0	-.0305
0545	52.4	49.4	33.55	11	334		6.49	37.88	0	-.0259		6.49	32.12	+.0004	-.0006		5.06	29.26	+.0009	+.0146		13.53	38.95	0	-.0468
0600	52.4	49	33.37	8	317		4.72	35.06	0	-.0121		4.72	29.47	.0008	+.0129		3.68	25.93	0011	+.0253		9.84	35.06	0	-.0198

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FIGURE 9. Ice/Frost Computer Predictions

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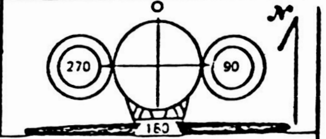
STS-27R	TEST: S0007, LAUNCH			DATE: 12/02/88	T-0 TIME: 0931 DATE: 12/02/88
ORBITER OV-104	ET 23	SRB BI030	MLP 1	PAD 39B	
LO$_2$	CHILLDOWN TIME: 2246 SLOW FILL TIME: 2300	FAST FILL TIME: 0201 REPLENISH TIME: 0409	LH$_2$	CHILLDOWN TIME: 2246 SLOW FILL TIME: 2256	FAST FILL TIME: 2325 REPLENISH TIME 0220



	LOCAL TIME	CONDITIONS					LO$_2$ TANK STA 370 TO 540					LO$_2$ TANK STA 550 TO 852					LH$_2$ TANK STA 1130 TO 1380					LH$_2$ TANK STA 1380 TO 2058				
		TEMP. °F	REL HUM. %	DEW PT °F	WIND VEL KNTS	WIND DIR DEG	REGION	LOCAL VEL KNTS	SOFI TEMP °F	COND RATE IN/HR	ICE RATE IN/HR	REGION	LOCAL VEL KNTS	SOFI TEMP °F	COND RATE IN/HR	ICE RATE IN/HR	REGION	LOCAL VEL KNTS	SOFI TEMP °F	COND RATE IN/HR	ICE RATE IN/HR	REGION	LOCAL VEL KNTS	SOFI TEMP °F	COND RATE IN/HR	ICE RATE IN/HR
	0615	52.4	48.4	33.11	8	311		4.72	35.04	0	-.0116		4.72	29.36	.0007	+.0134		3.68	25.82	.0011	+.0257		9.84	35.04	0	-.0189
	0630	51.6	49	32.75	10	308		5.90	36.28	0	-.0169		5.90	30.64	.0005	+.0082		4.60	27.49	.0009	+.0218		12.30	36.71	0	-.0304
	0645	51.2	50.4	33.04	8	323		4.72	33.94	0	-.0080		4.72	28.61	.0008	+.0170		3.68	25.00	.0011	+.0289		9.84	33.93	0	-.0131
	0700	51	50	32.72	12	304		7.08	37.27	0	-.0228		7.08	31.67	.0003	+.0024		5.52	28.86	.0008	+.0174		14.76	37.95	0	-.0428
	0715	50	53.2	33.25	10	306		5.90	34.82	0	-.0128		5.90	29.95	.0008	+.0122		4.60	26.71	.0012	+.0255		12.30	35.23	0	-.0238
	0730	50.2	53.2	33.41	9	311		5.31	34.09	0	-.0099		5.31	29.24	.0009	+.0152		4.14	25.81	.0012	+.0277		11.07	34.32	0	-.0177
	0745	50.8	52.2	33.47	11	305		6.49	36.40	0	-.0201		6.49	31.24	.0006	+.0051		5.06	28.26	.0011	+.0196		13.53	36.95	0	-.0372
	0800	52	51.8	34.35	8	305		4.72	34.77	0	-.0128		4.72	29.64	.0009	+.0123		3.68	26.07	.0012	+.0250		9.84	34.71	0	-.0211
	0815	53,6	51.6	35.80	7	318		4.13	35.36	+.0001	-.0148		4.13	29.90	+.0010	+.0103		3.22	26.15	.0013	+.0229		8.61	35.11	+.0002	-.0227
	0830	54	51.4	36.08	8	321		4.72	36.76	0	-.0217		4.72	31.46	+.0009	+.0036		3.68	27.99	.0012	+.0175		9.84	36.63	0	-.0355
	0845	54.8	52.6	37.46	8	332		4.72	37.59	0	-.0266		4.72	32.26	+.0010	-.0011		3.68	29.03	.0013	+.0135		9.84	37.44	0	-.0437
	0900	55.6	54.4	39.13	9	328		5.31	39.51	0	-.0384		5.31	34.42	+.0010	-.0126		4.14	31.41	.0013	+.0042		11.07	39.51	0	-.0651
	0915	56	55.4	40	9	326		5.31	39.98	0	-.0416		5.31	35.04	0011	-.0157		4.14	31.98	+.0014	+.0016		11.07	39.96	0	-.0705
T-0	0930.34	58.2	59.2	43.91	9	356		5.31	42.94	.0003	-.0580		5.31	38.10	.0014	-.0315		3.96	34.15	+.0017	-.0093		8.91	41.47	0010	-.0716
AVG		53.7	50.4	35.19	9	320 NW			37.6					32.1					28.7					37.5		

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FIGURE 10. Ice/Frost Computer Predictions

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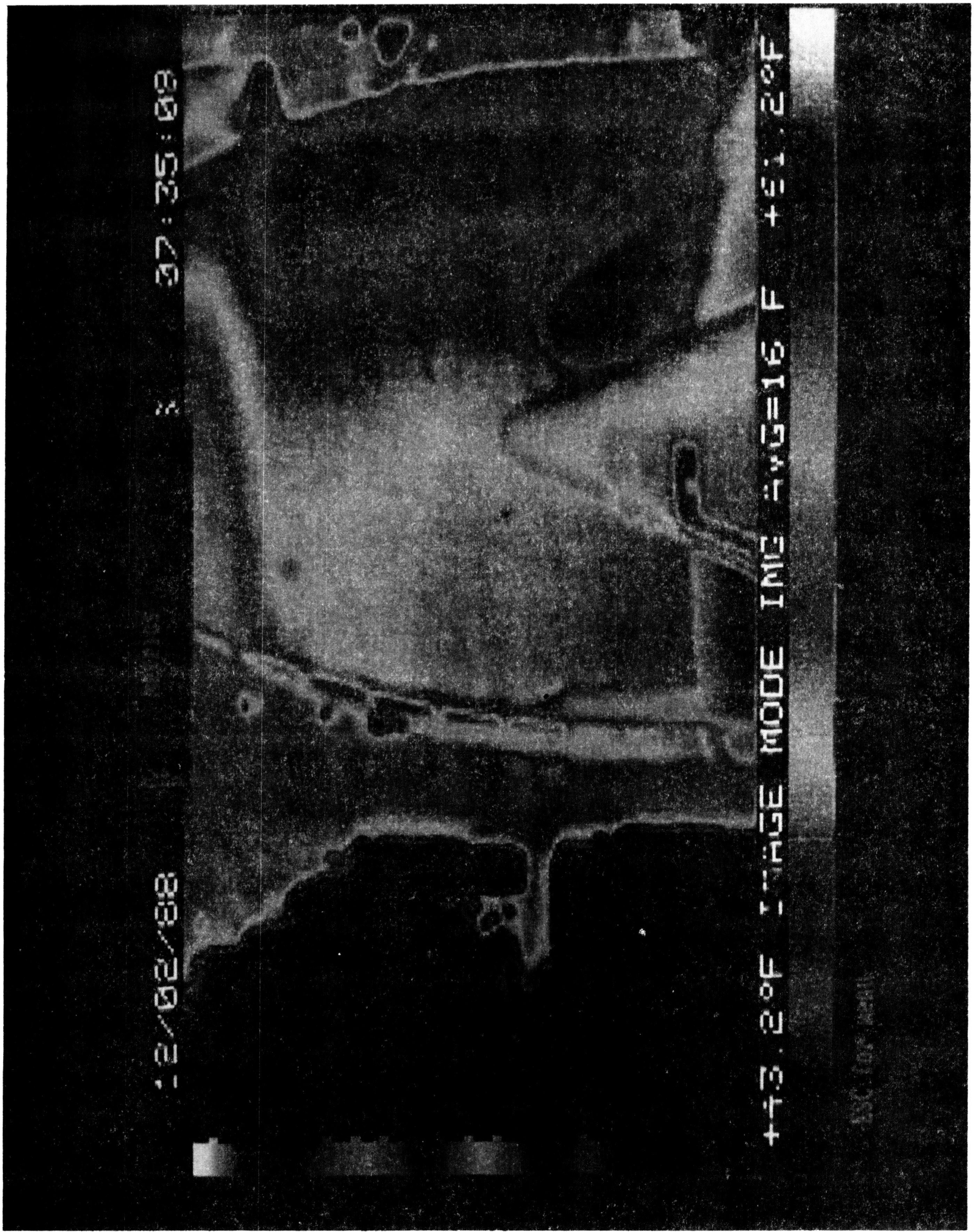
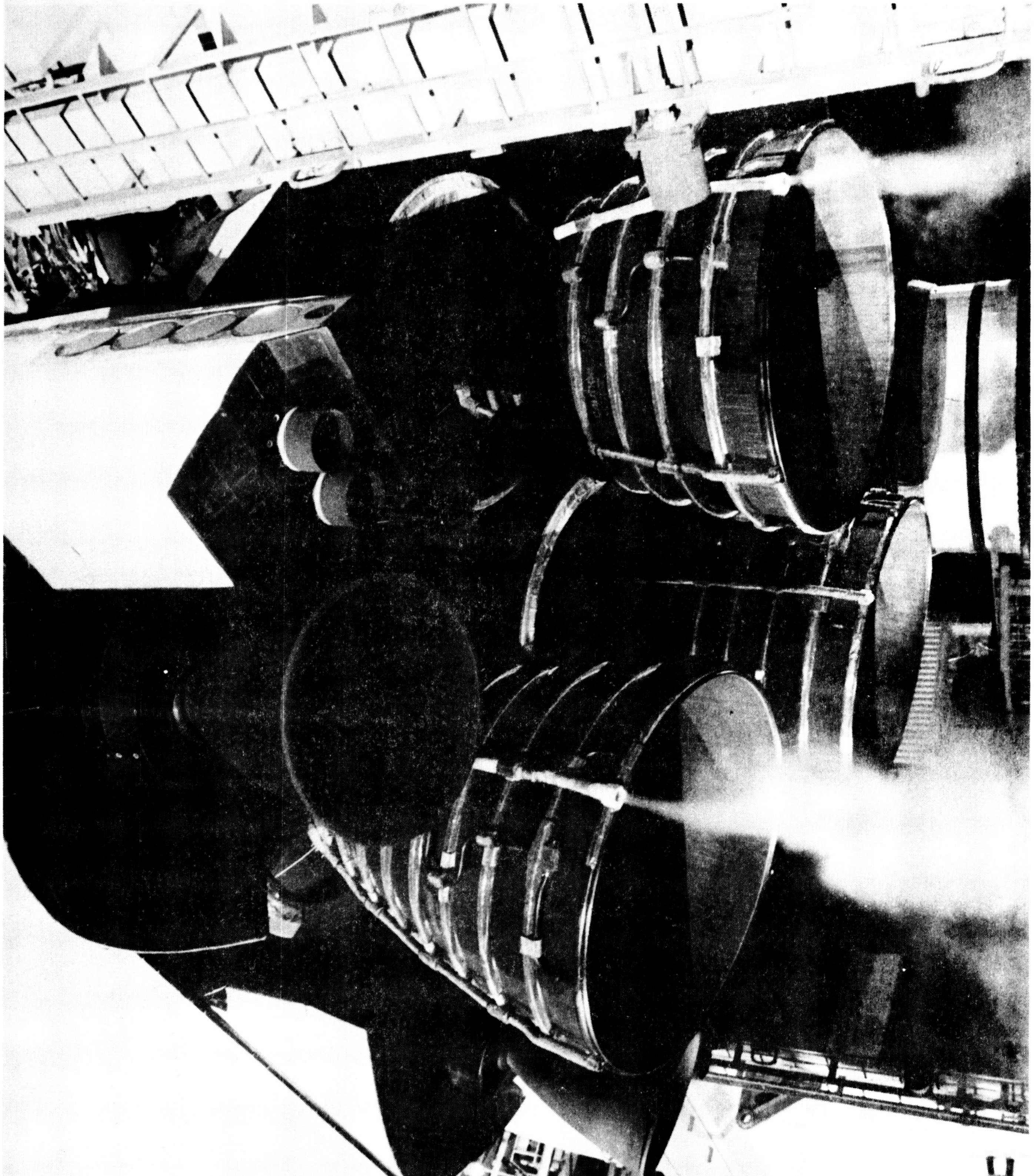


INFRARED IMAGE OF +Y SIDE OF ET LO2 TANK OGIVE AND RH SRB NOSECAP TAKEN BY C/S-2 STI UNIT. NO ANOMALIES VISIBLE.



LIGHT FROST BUILD-UP ON SSME GOX VENTS

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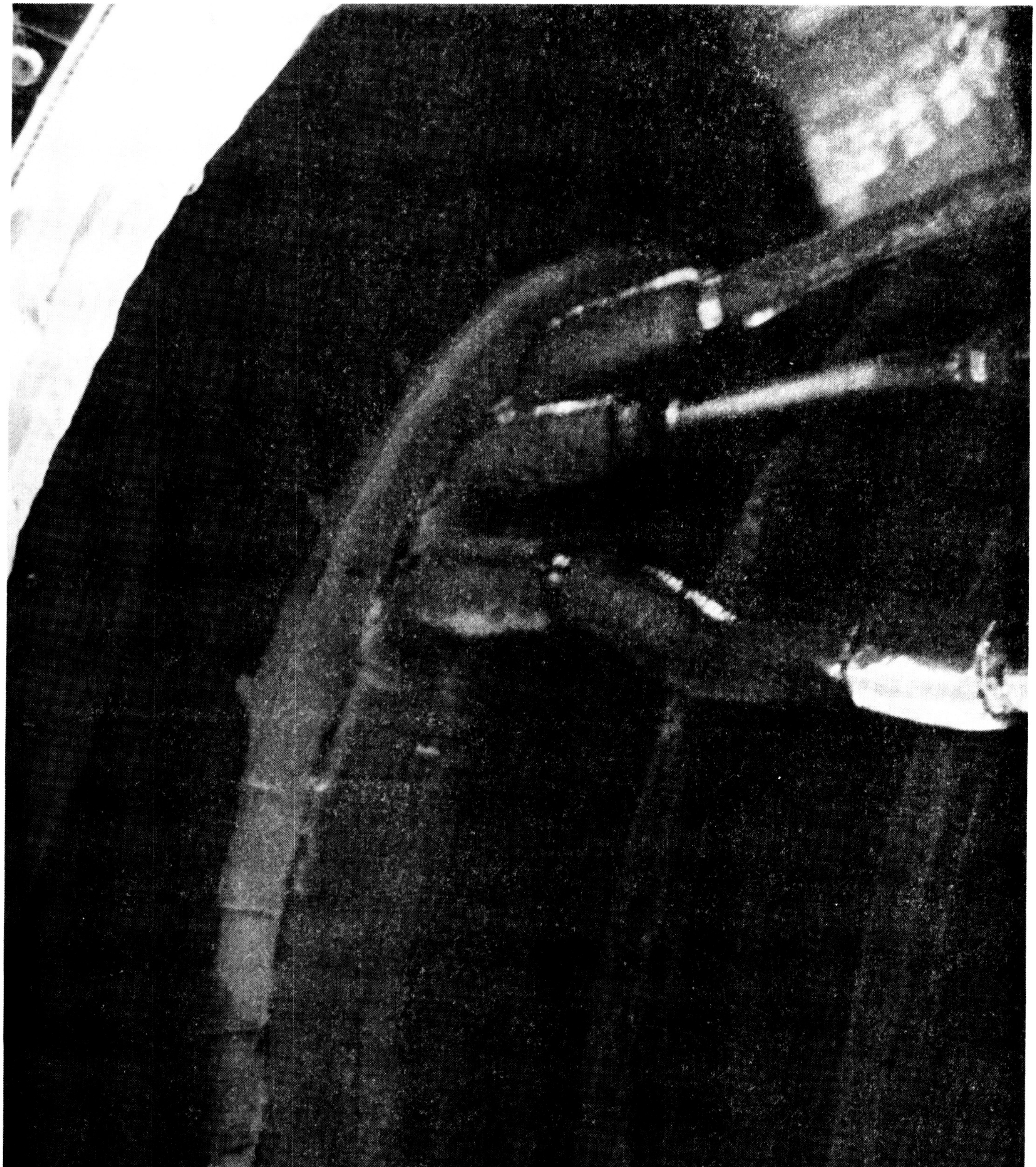

LIGHT FROST ACCUMULATION ON ENGINE MOUNTED HEAT SHIELD

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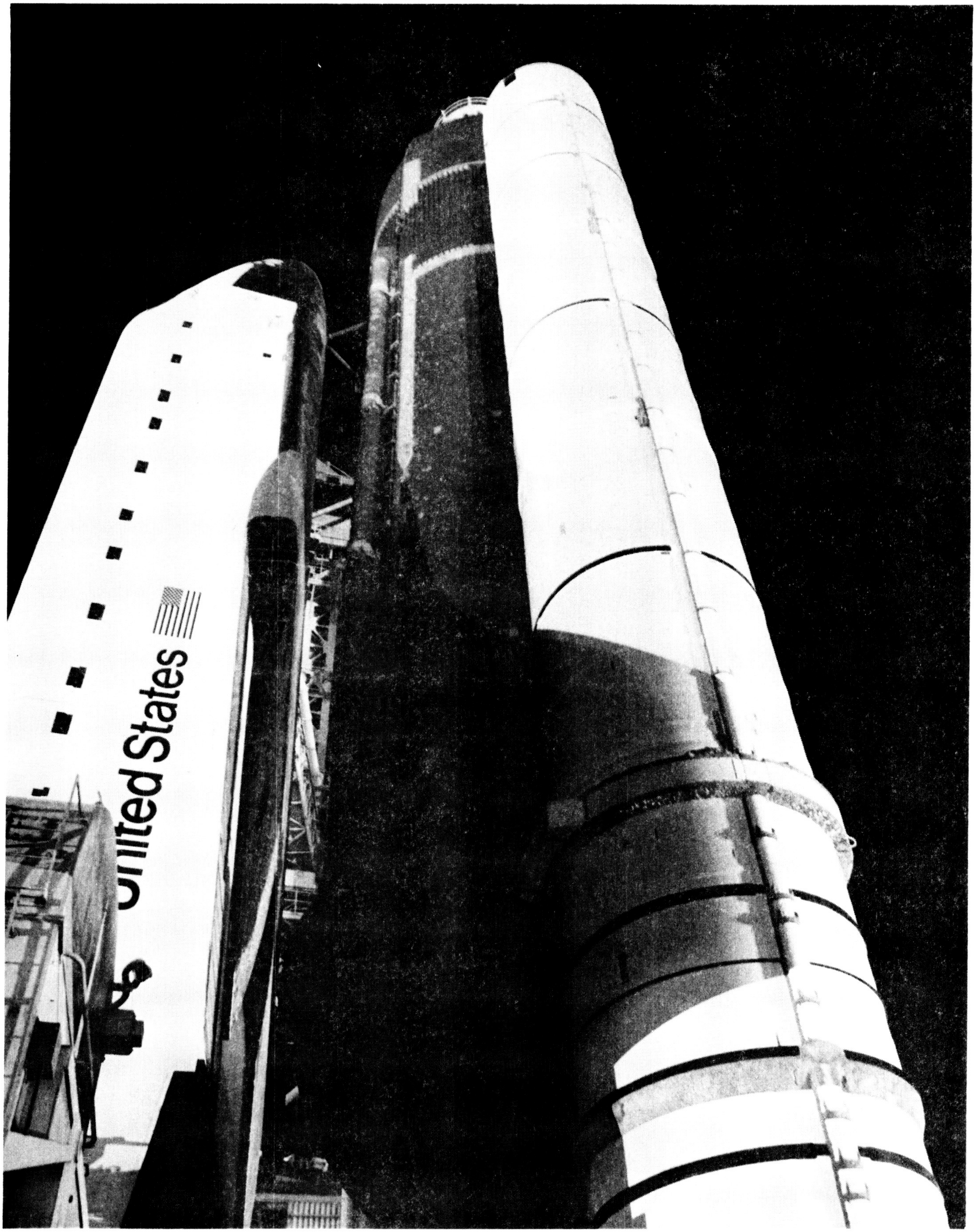
WHITE SPOT NOTED ON LH ORBITER WING LEADING EDGE RCC T-SEAL



OVERALL VIEW OF VEHICLE RH SIDE.
NO ACREAGE ICE/FROST.

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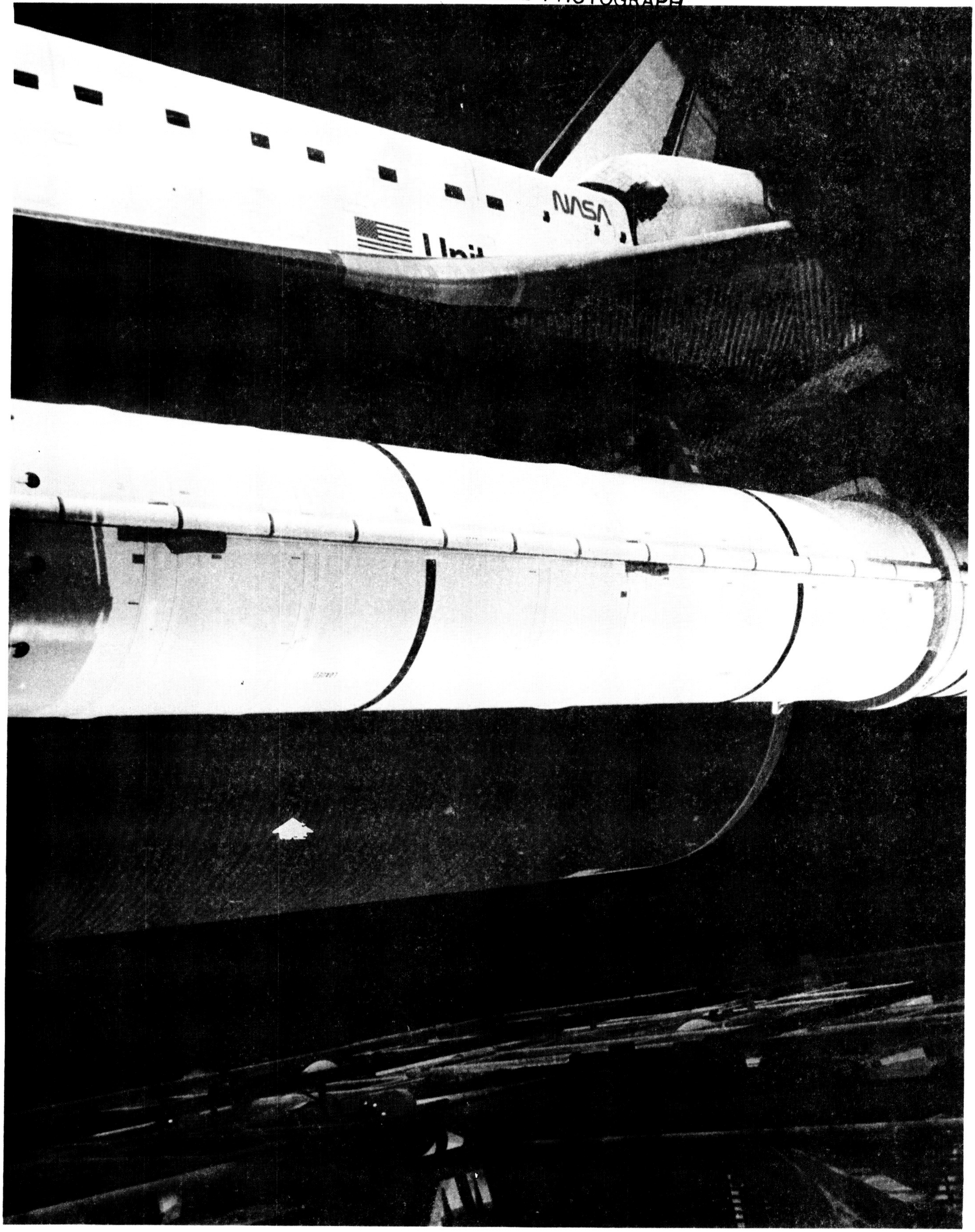

LIGHT ACREAGE FROST VISIBLE ON MID LH2 TANK
BARREL AT 315° DEGREES AZIMUTH

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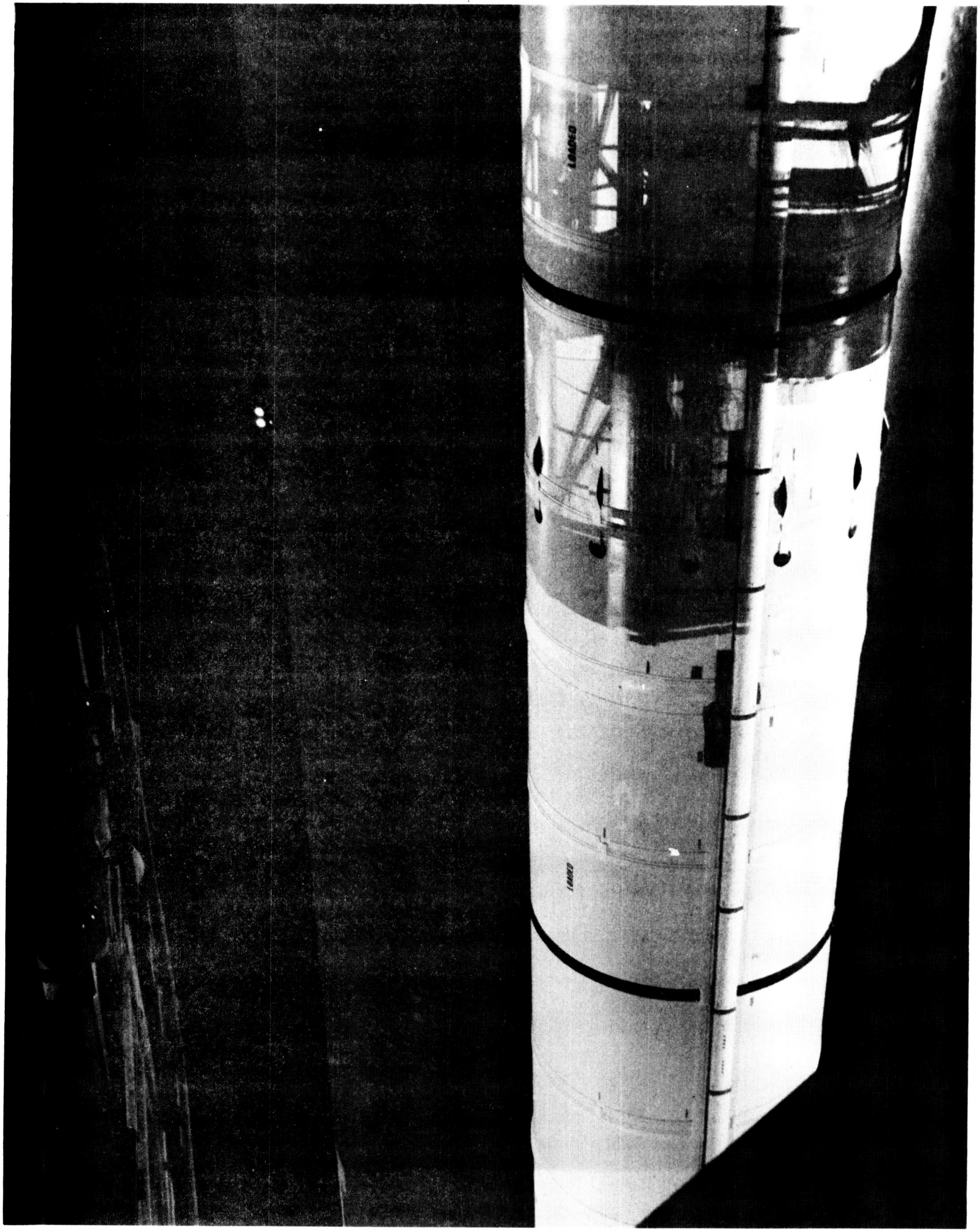

LIGHT CONDENSATE VISIBLE PRIMARILY ON UPPER LH2 TANK BARREL.
ACREAGE FROST ON MID LH2 BARREL AT 315° AZIMUTH.

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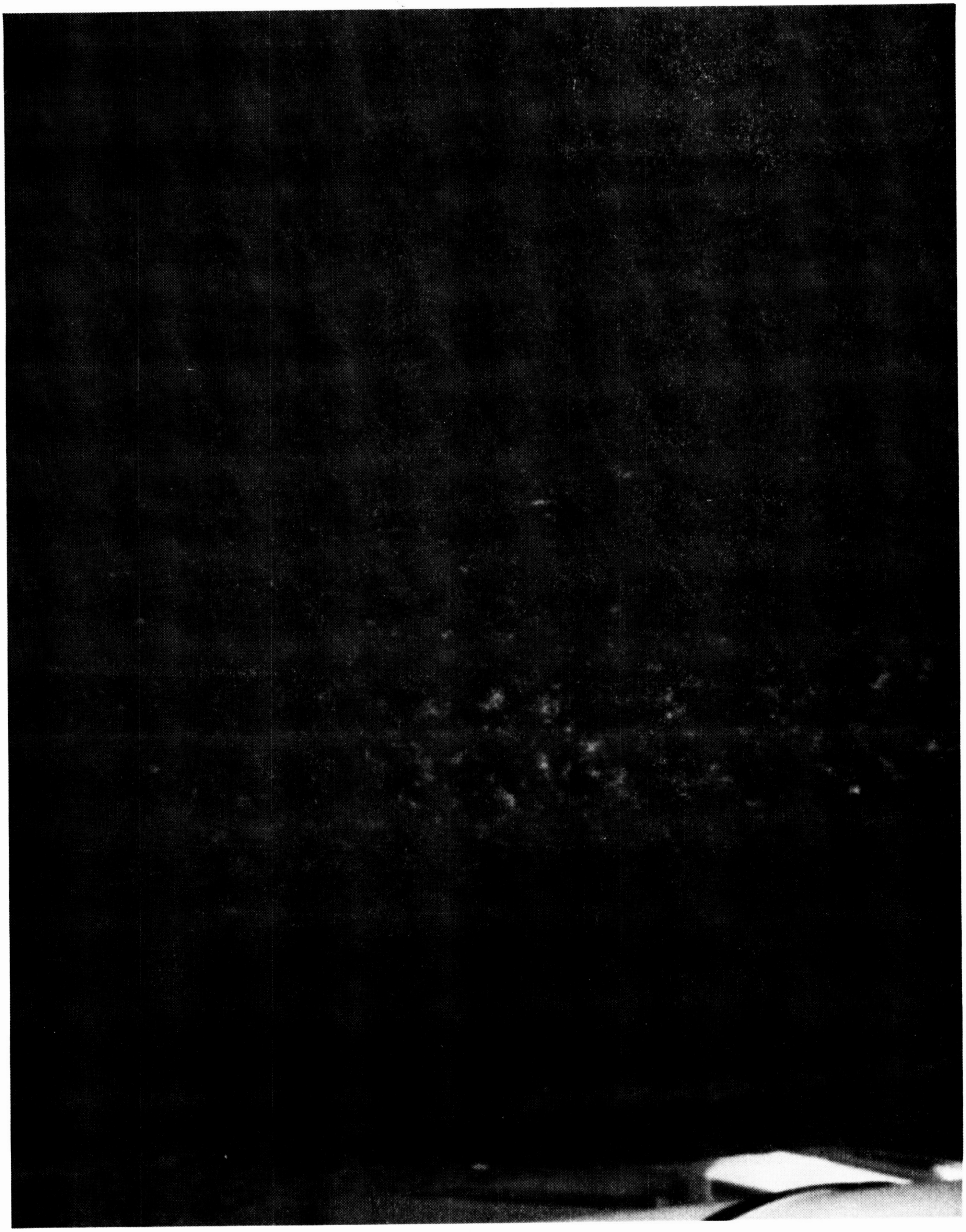

CLOSEUP OF FROST ON MID LH2 TANK BARREL AT 315° AZIMUTH

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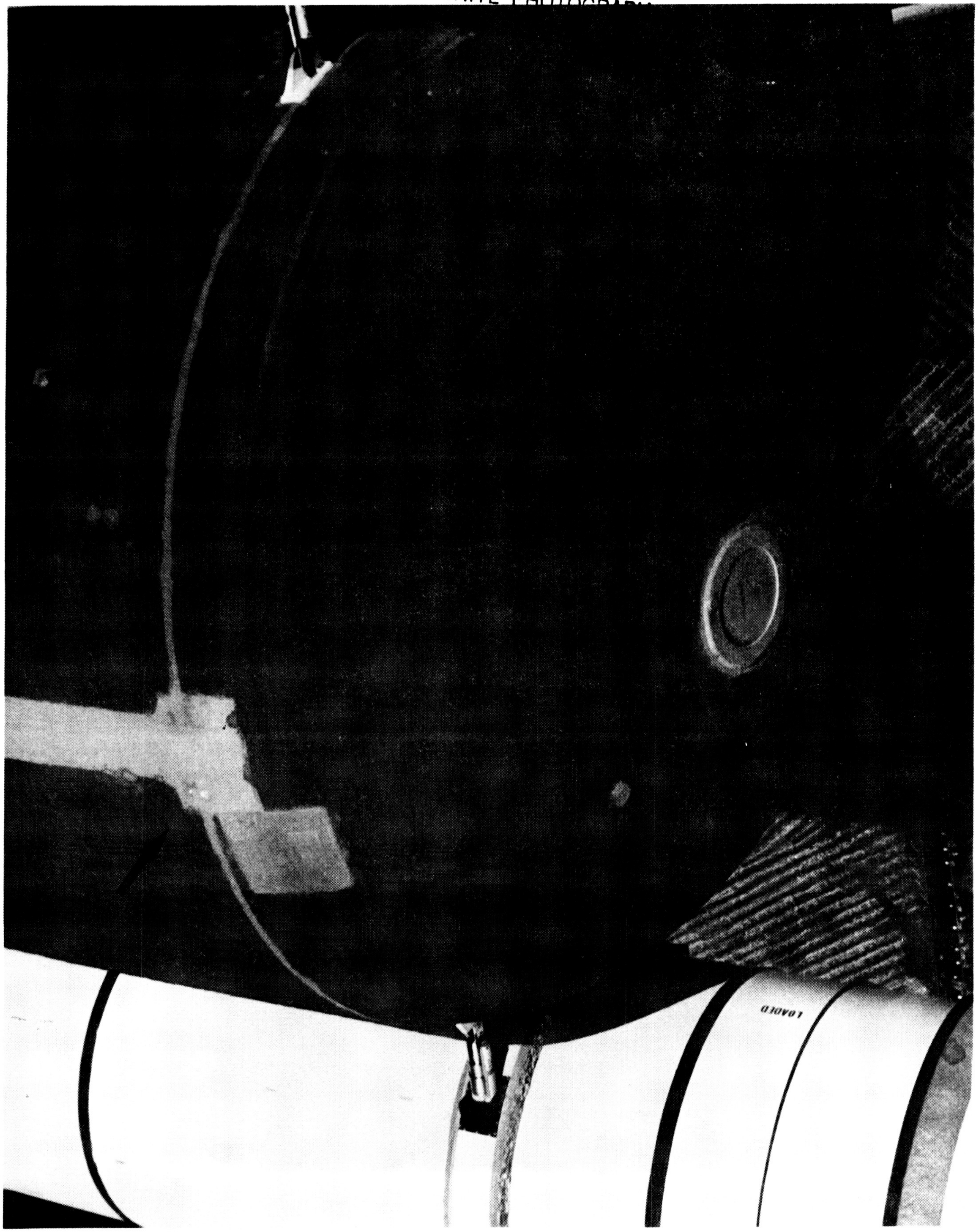
ET LH2 TANK AFT DOME, LH2 AND LO2 ET/ORB UMBILICALS, AND LH SIDE OF ORBITER. NO ANOMALIES VISIBLE



ET LH2 TANK AFT DOME. NOTE FROST ON EB FITTINGS AND FROST AREAS ON AFT (-Z) HARDPOINT CLOSEOUT.

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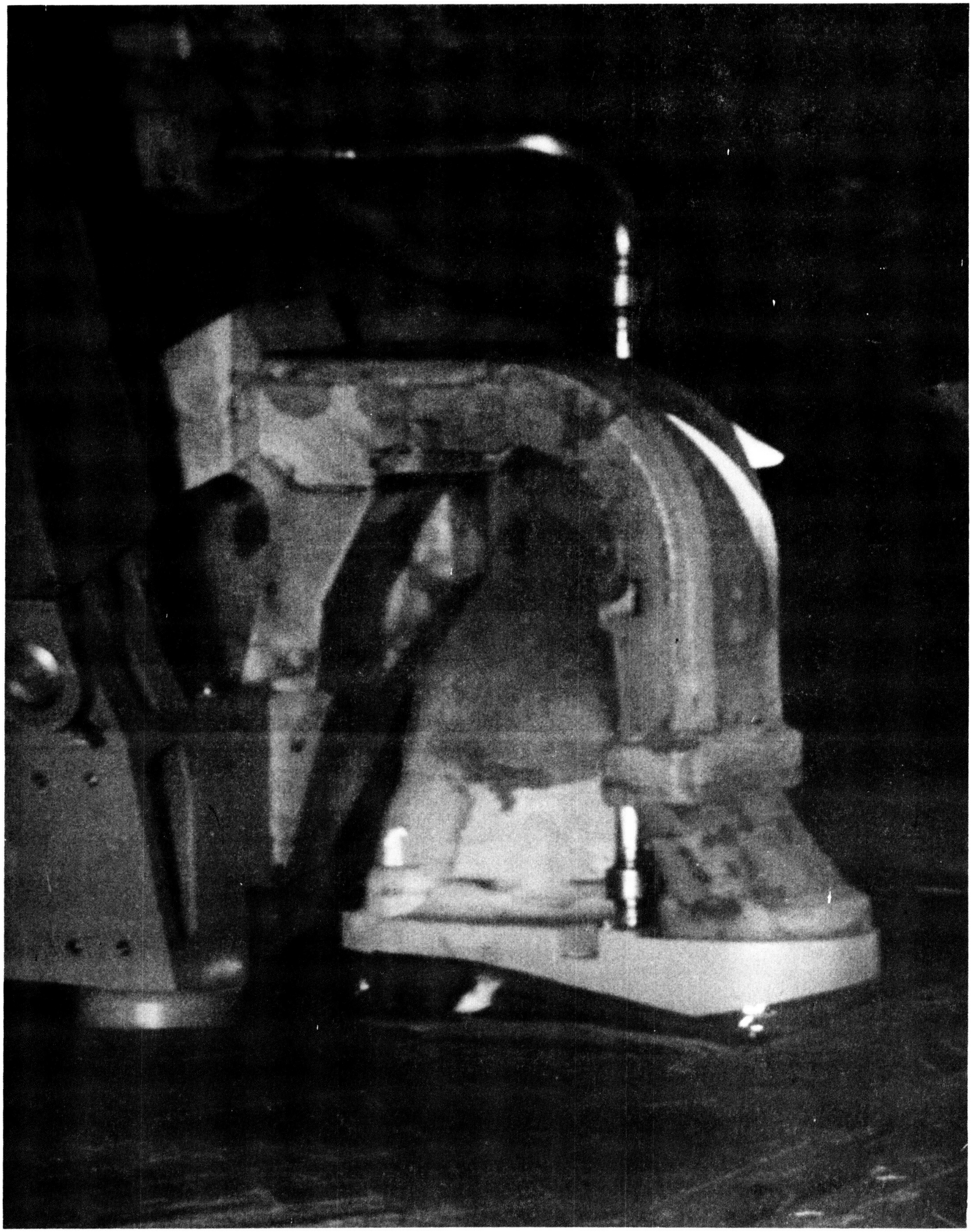

LIGHT ICE/FROST ACCUMULATION ON ET/ORB LO2 UMBILICAL.
TYPICAL FROST FINGER ON PURGE VENT.

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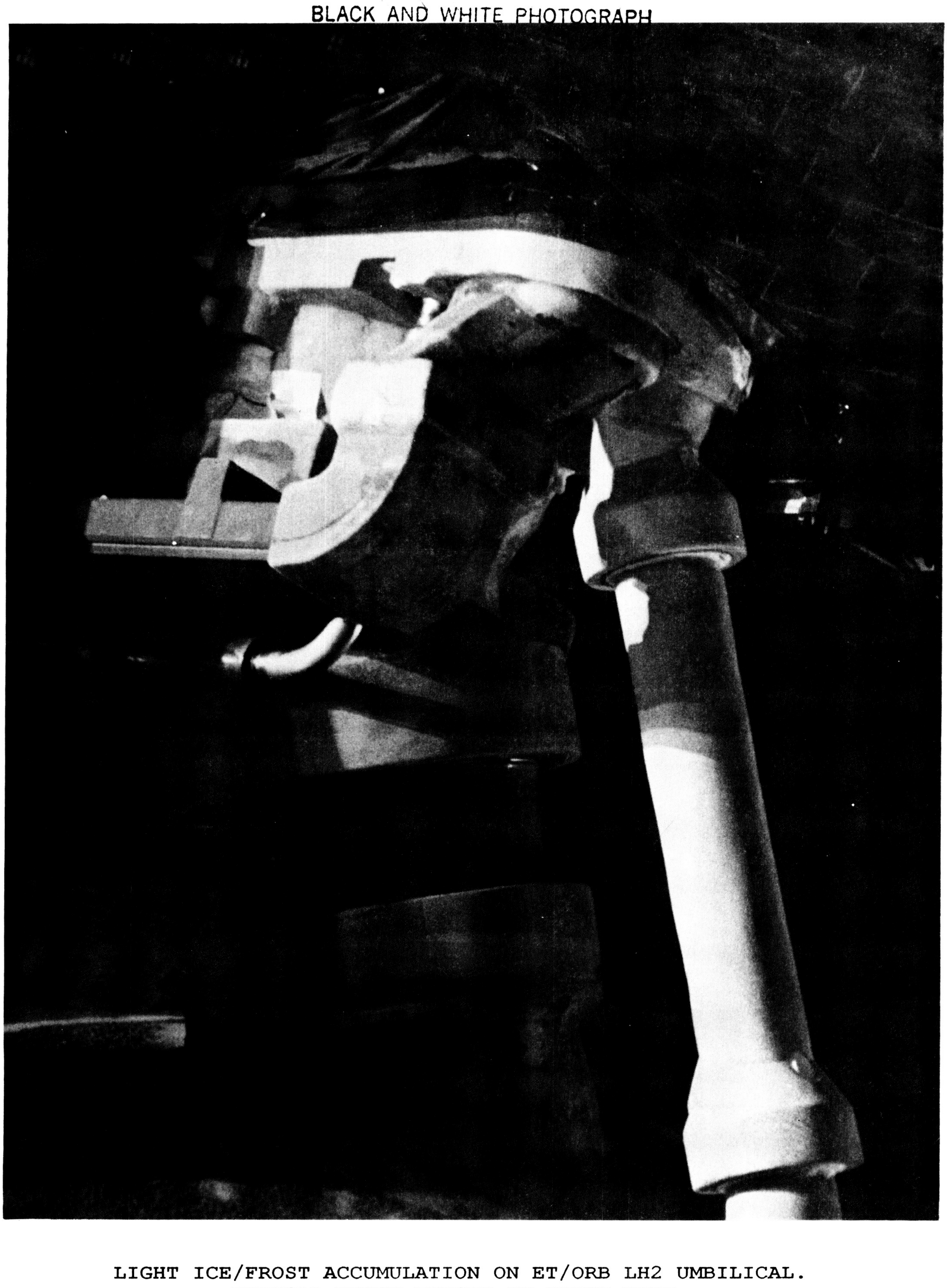
BLACK AND WHITE PHOTOGRAPH



LIGHT ICE/FROST ACCUMULATION ON ET/ORB LH2 UMBILICAL.
TYPICAL FROST FINGER ON PURGE VENT.

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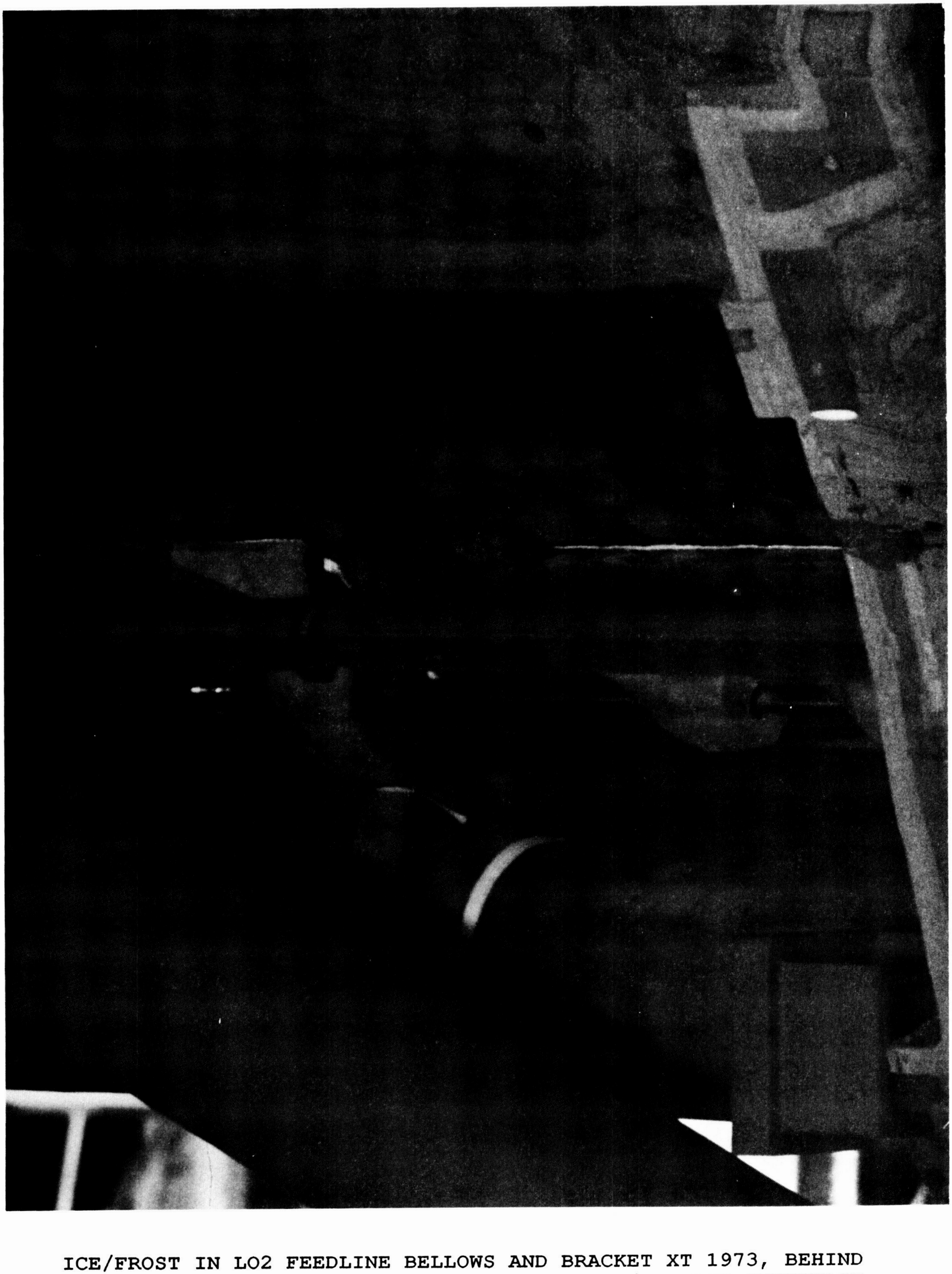
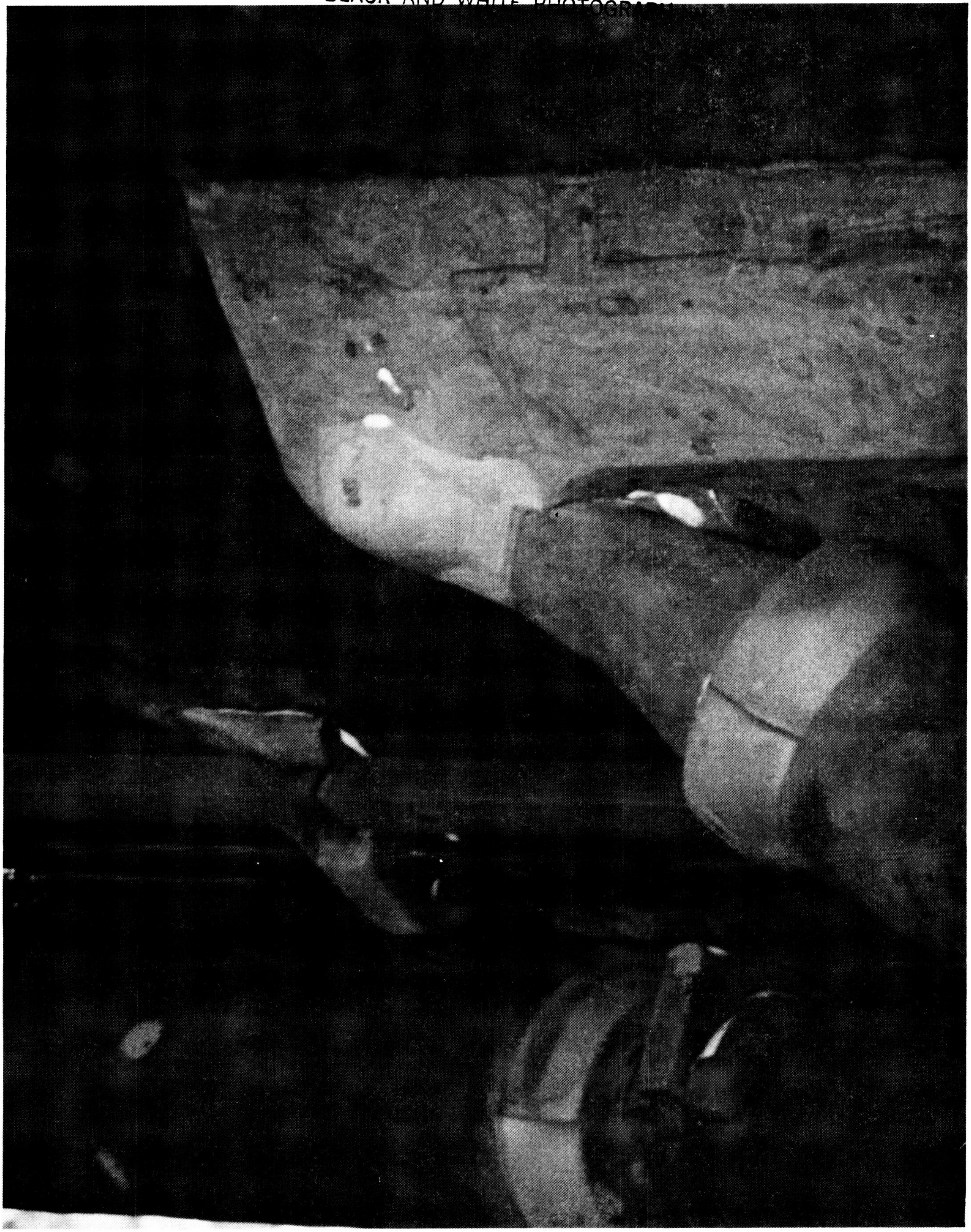


ICE/FROST IN LO2 FEEDLINE BELLOWS AND BRACKET XT 1973, BEHIND PRESSLINE BARRYMOUNT, AND ON CABLE TRAY RAMP/ACREAGE INTERFACE.



ICE/FROST ACCUMULATION ON CRACK IN +Y THRUST STRUT CROTCH AREA
AND IN THREE AREAS ON THRUST STRUT KNUCKLE

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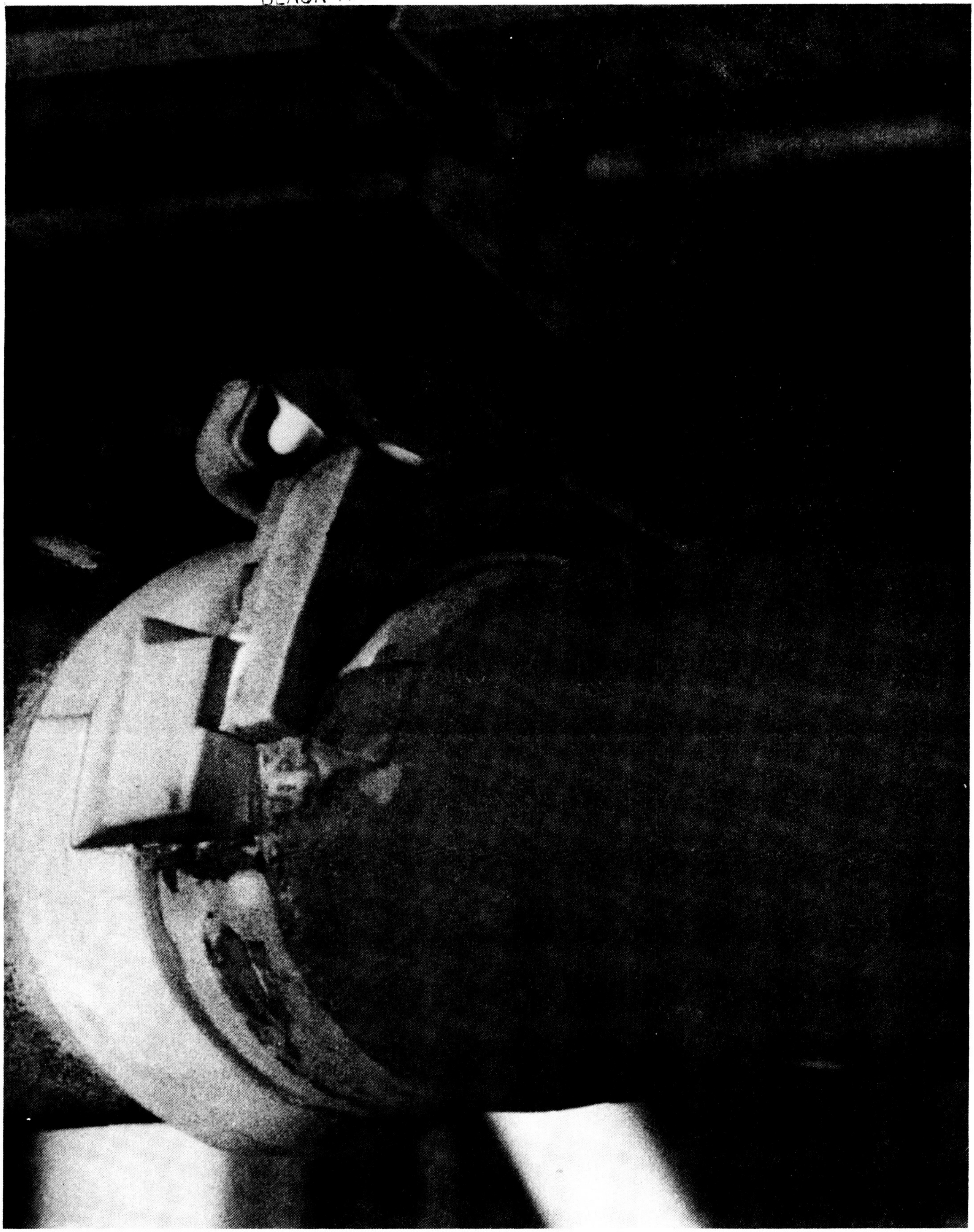
BLACK AND WHITE PHOTOGRAPH



ICE/FROST IN LO2 FEEDLINE SUPPORT BRACKET XT 1623

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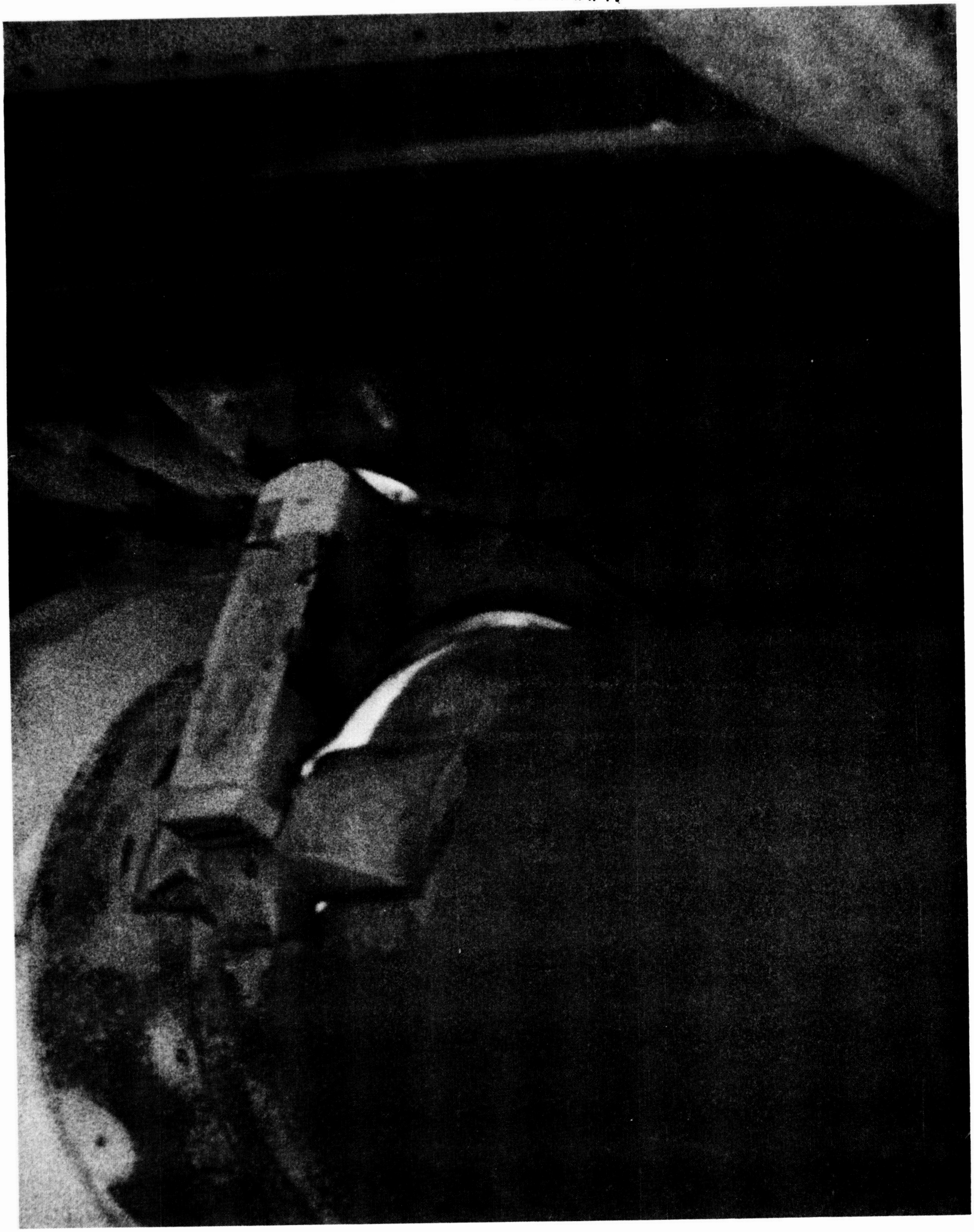

ICE/FROST IN LO2 FEEDLINE SUPPORT BRACKET XT 1871

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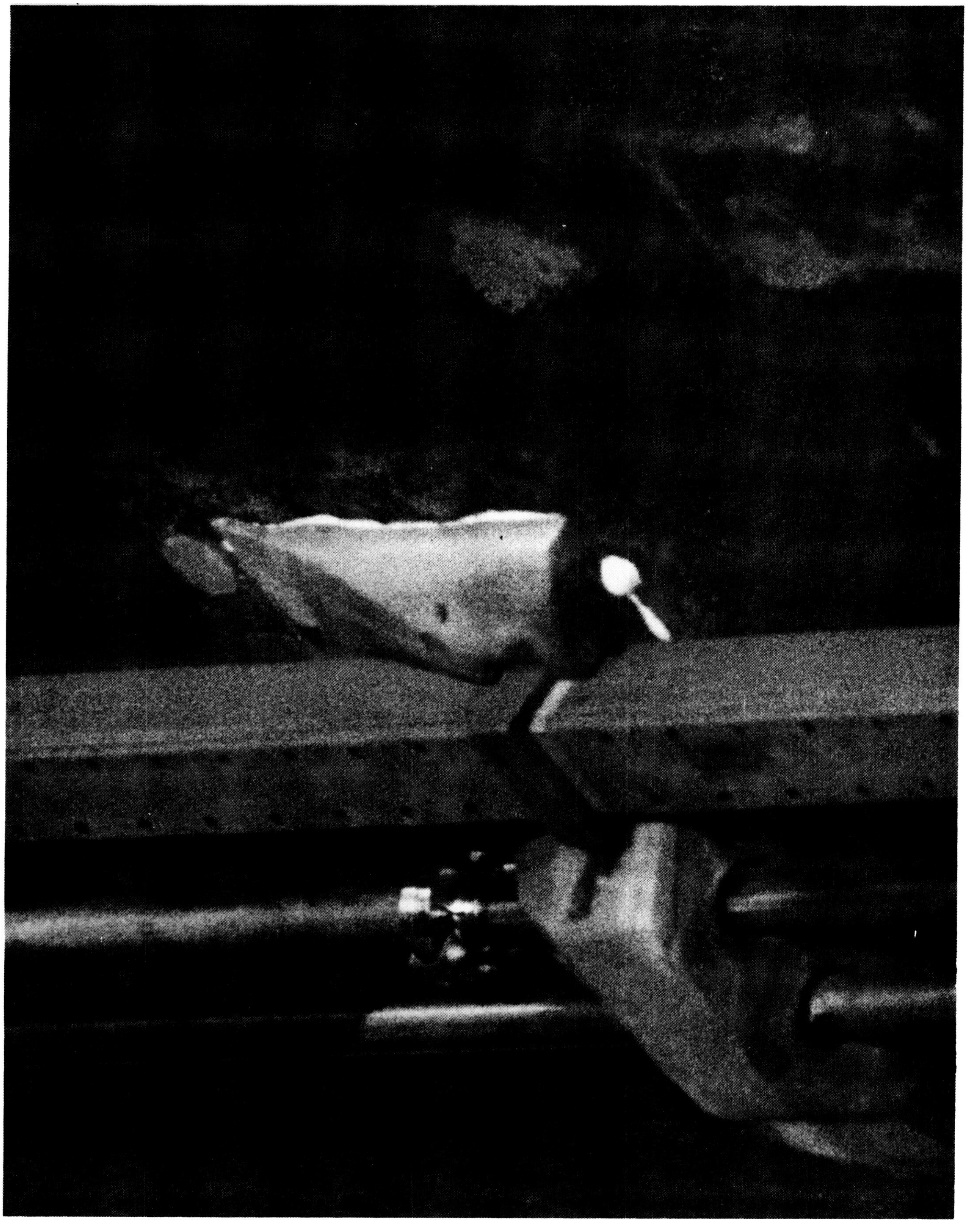
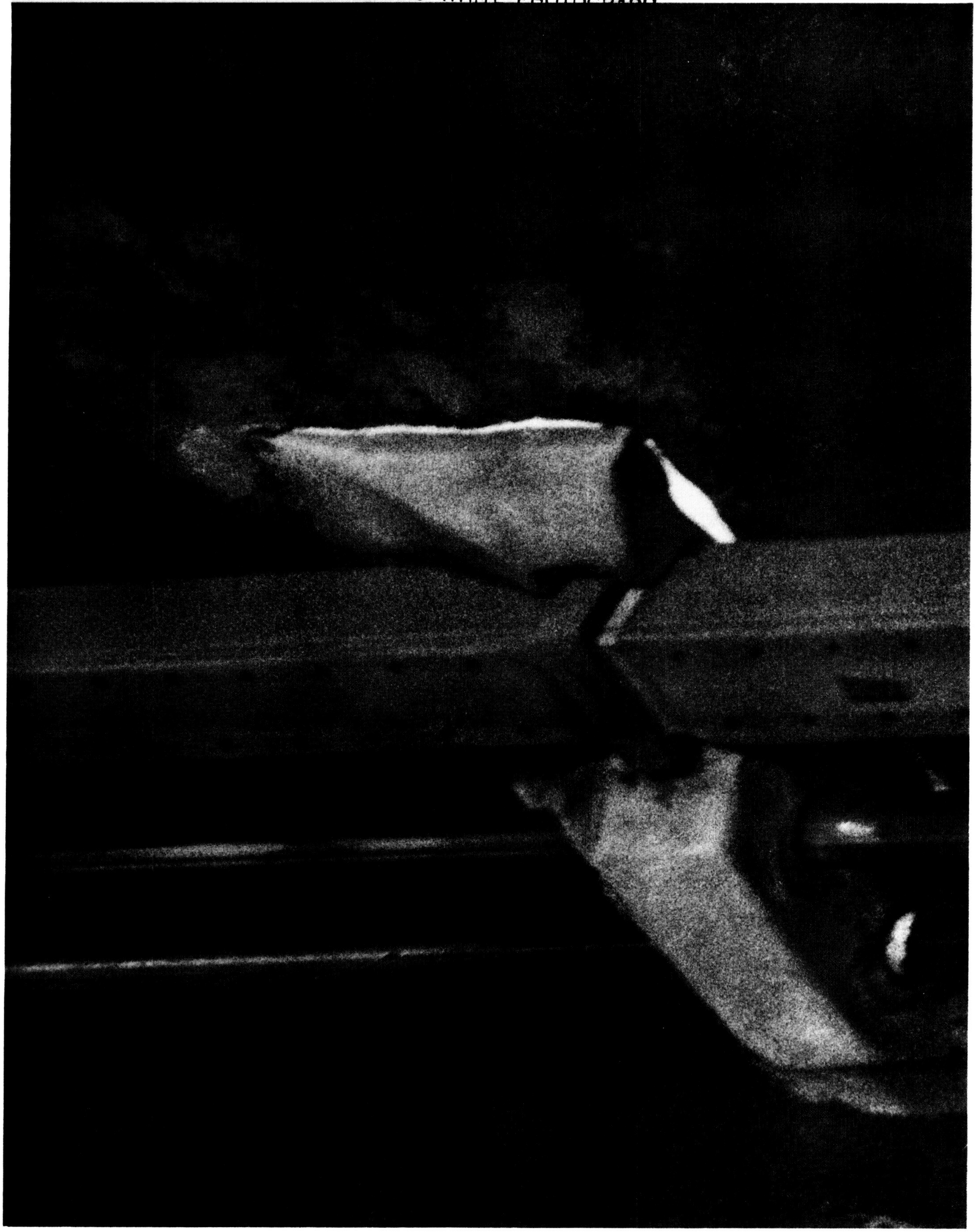
ICE/FROST ACCUMULATION IN LO2 FEEDLINE BELLOWS AT XT 1106



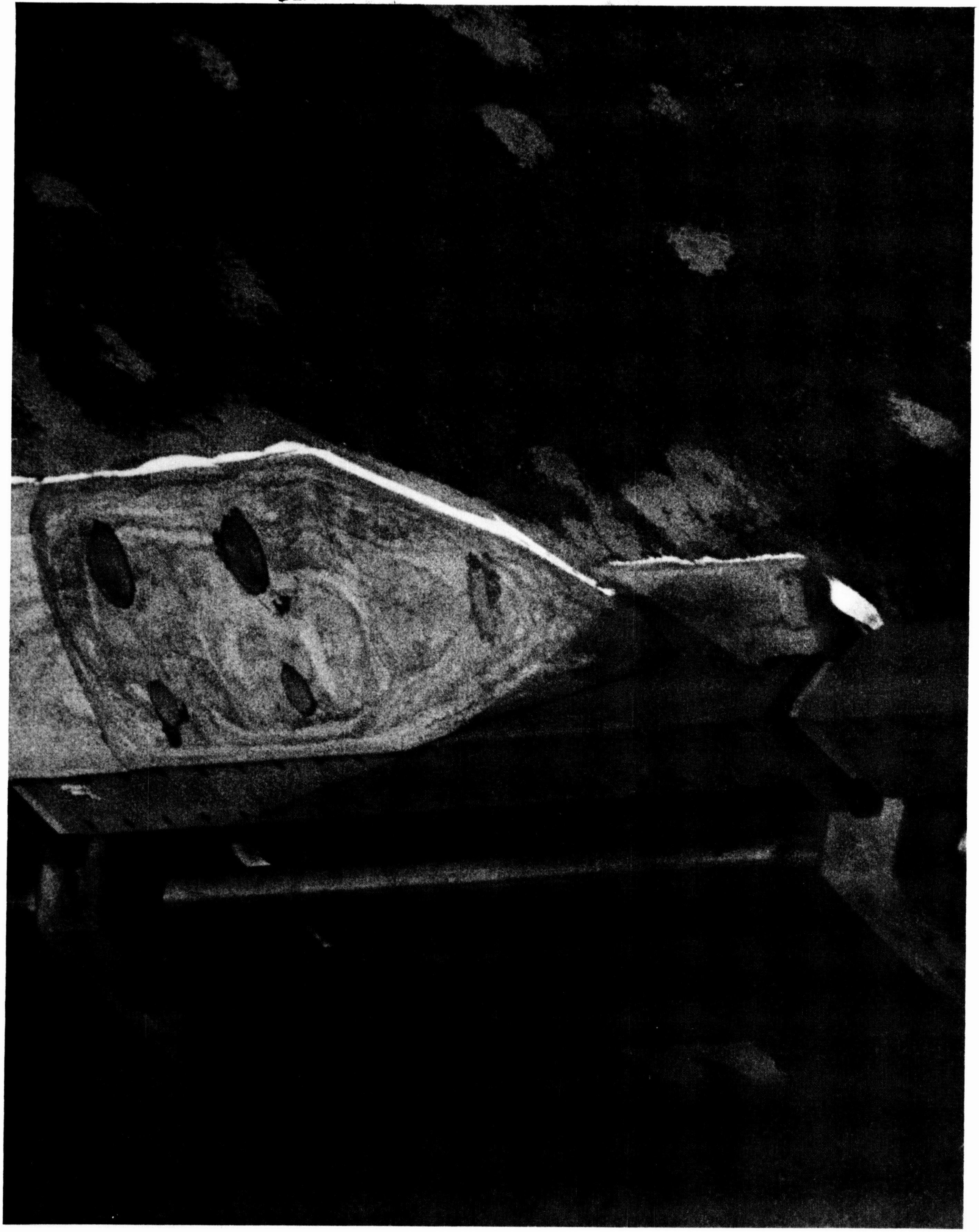
FROST ON CABLE TRAY RAMP TO ACREAGE INTERFACE

ORIGINAL PAGE
BLACK AND WHITE PHOTOGRAPH

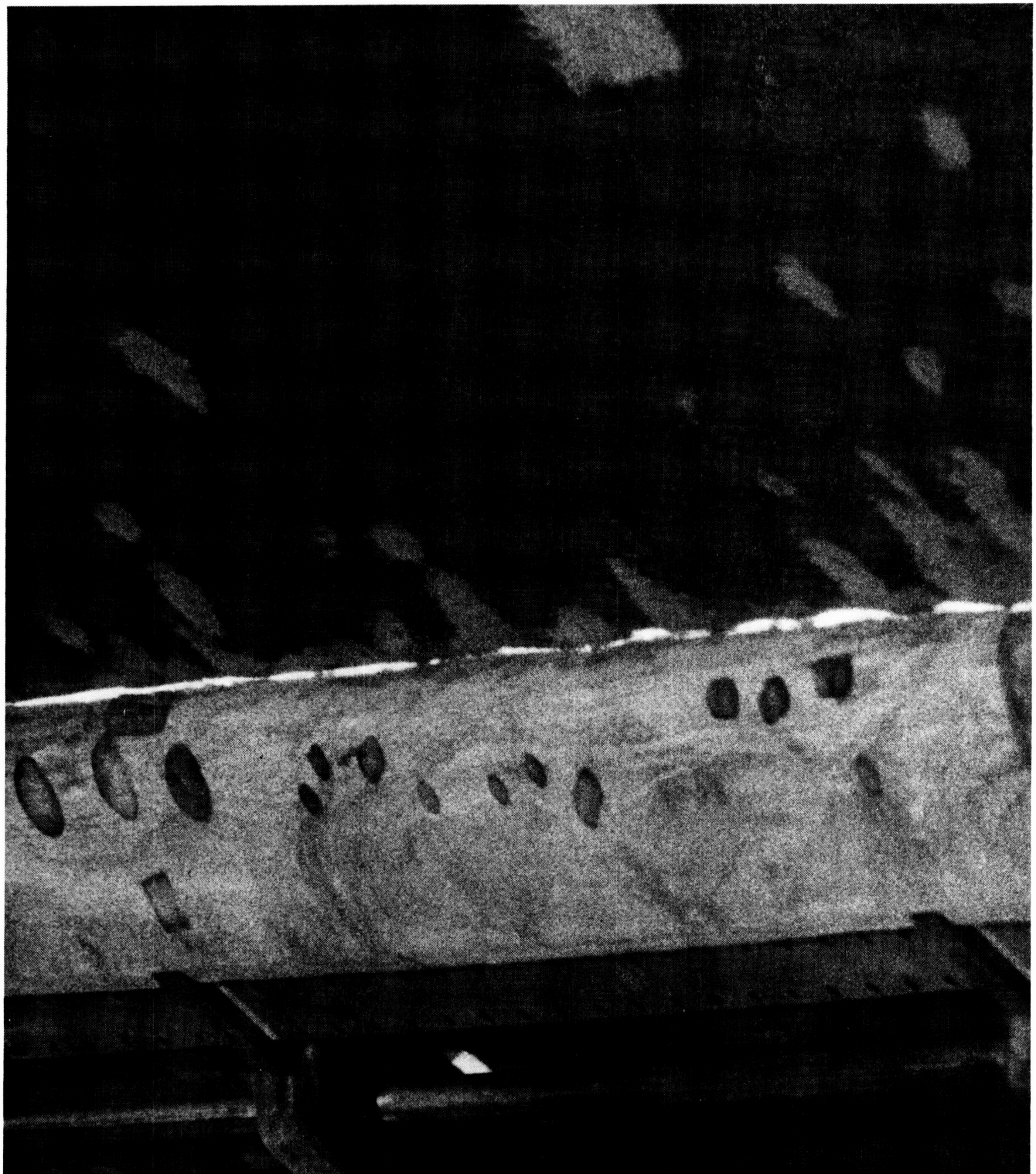


FROST ON CABLE TRAY RAMP TO ACREAGE INTERFACE.
TPS RESIDUE IS VISIBLE ON PRESSLINE.

ORIGINAL PAGE
BLACK AND WHITE PHOTOGRAPH



FROST ON LH2 PAL RAMP TO ACREAGE INTERFACE, CABLE TRAY RAMP TO ACREAGE INTERFACE, AND AFT OF GOX PRESSLINE BARRYMOUNT



FROST AT LH2 PAL RAMP TO ACREAGE INTERFACE
AND AFT OF GOX PRESSLINE BARRYMOUNT

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ORIGINAL PAGE
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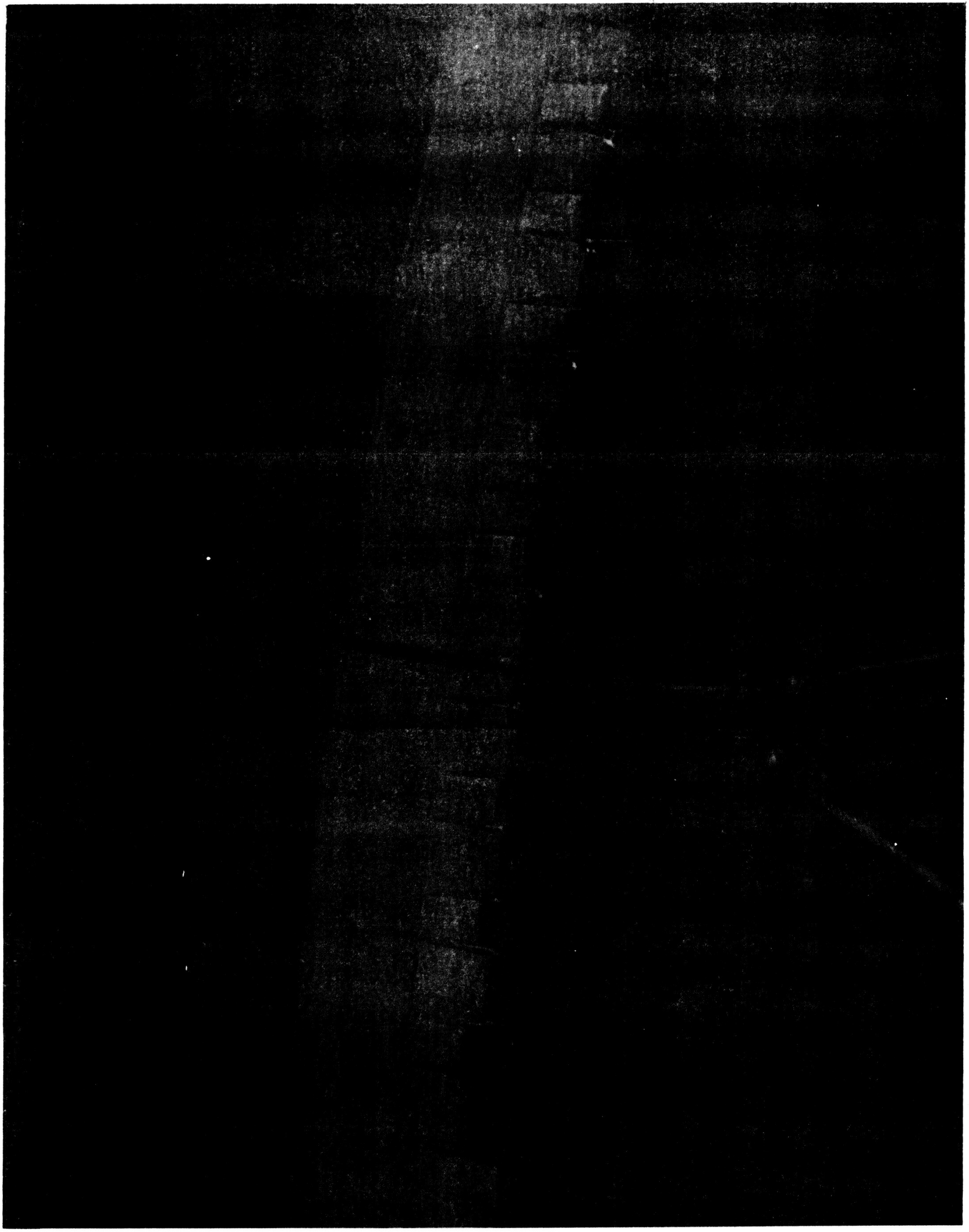
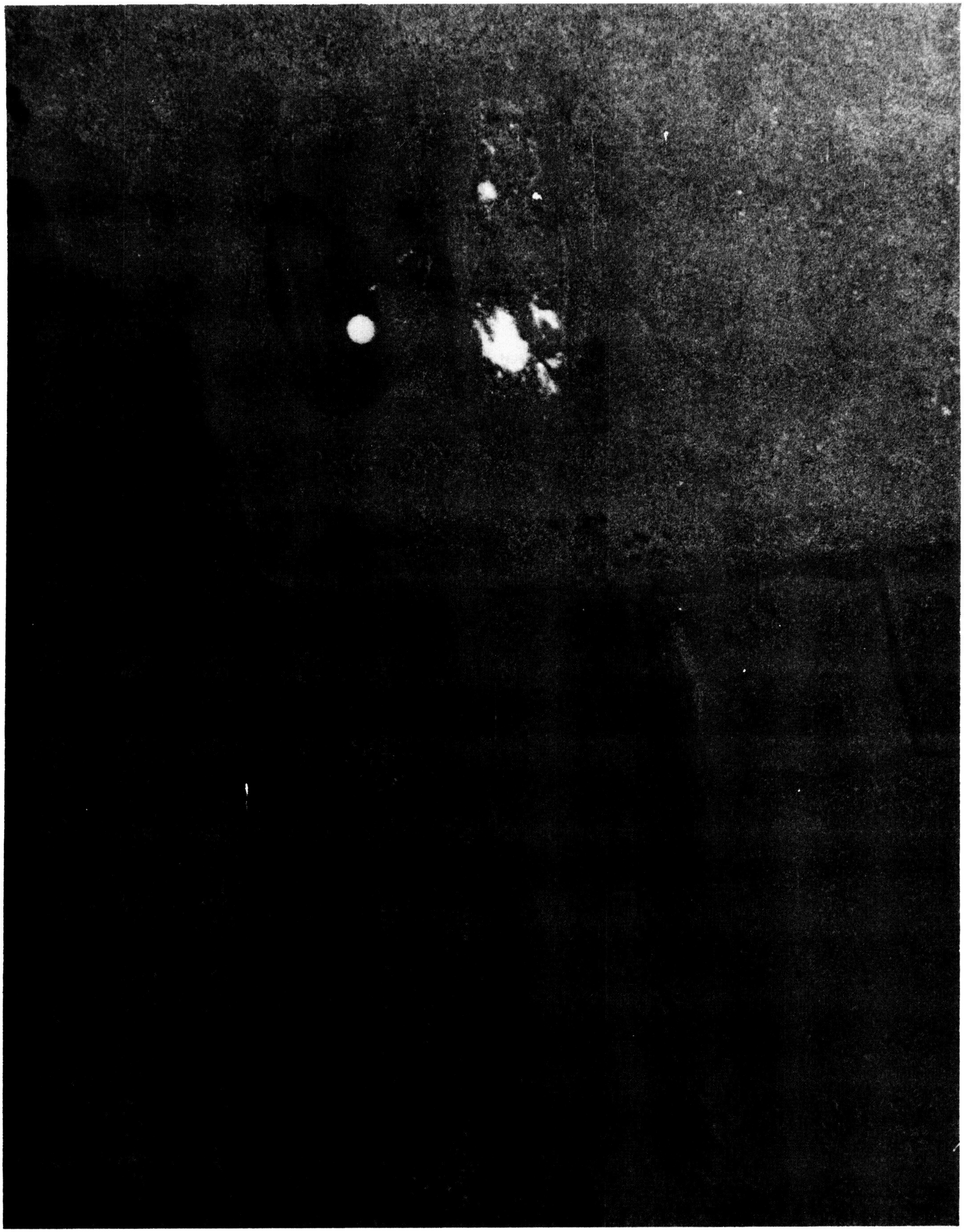


VERY LIGHT FROST ON INTERTANK STRINGER ROOTS AT LO2 TANK FLANGE



FROST AREAS ON THE AFT HARDPOINT CLOSEOUT PAD

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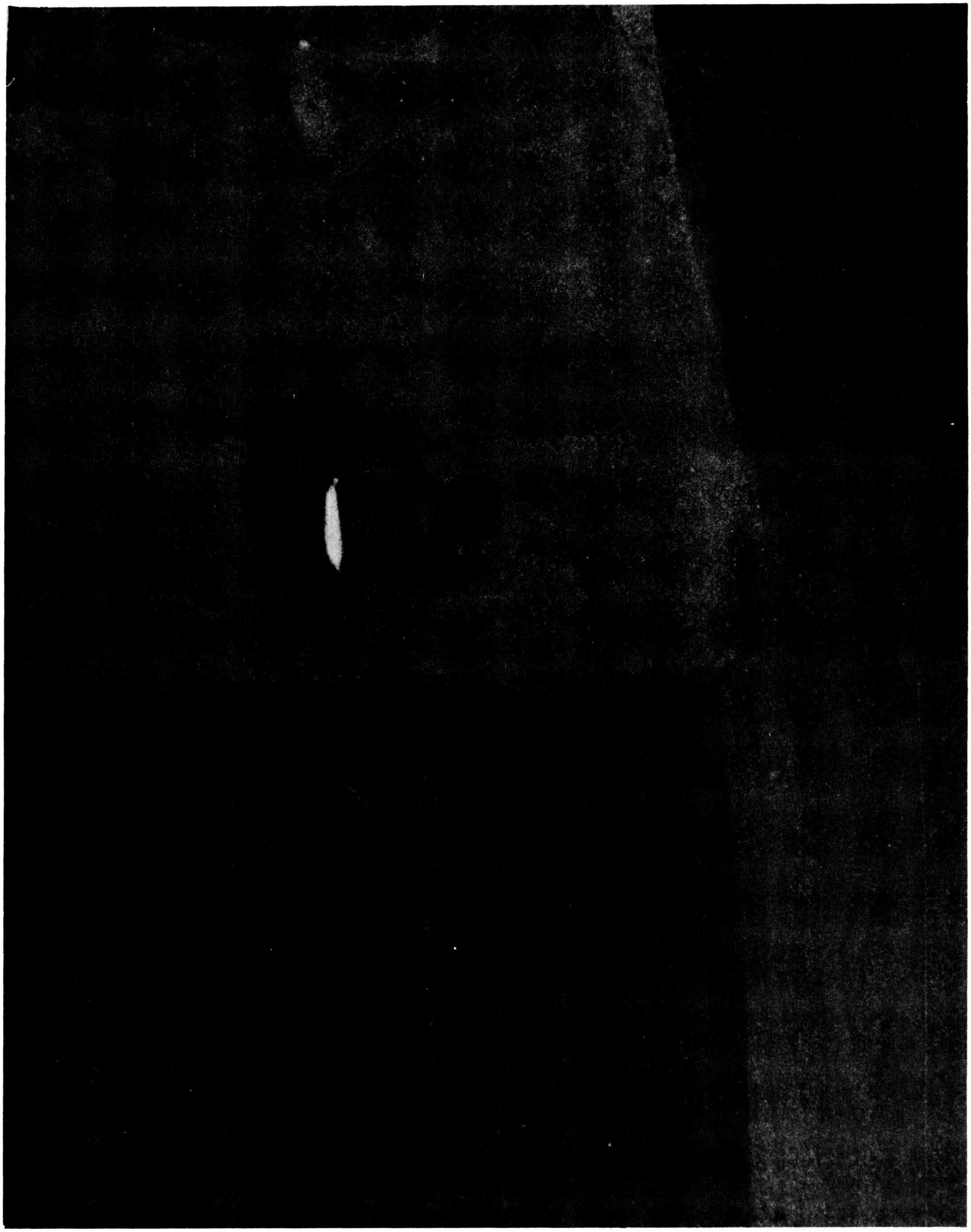
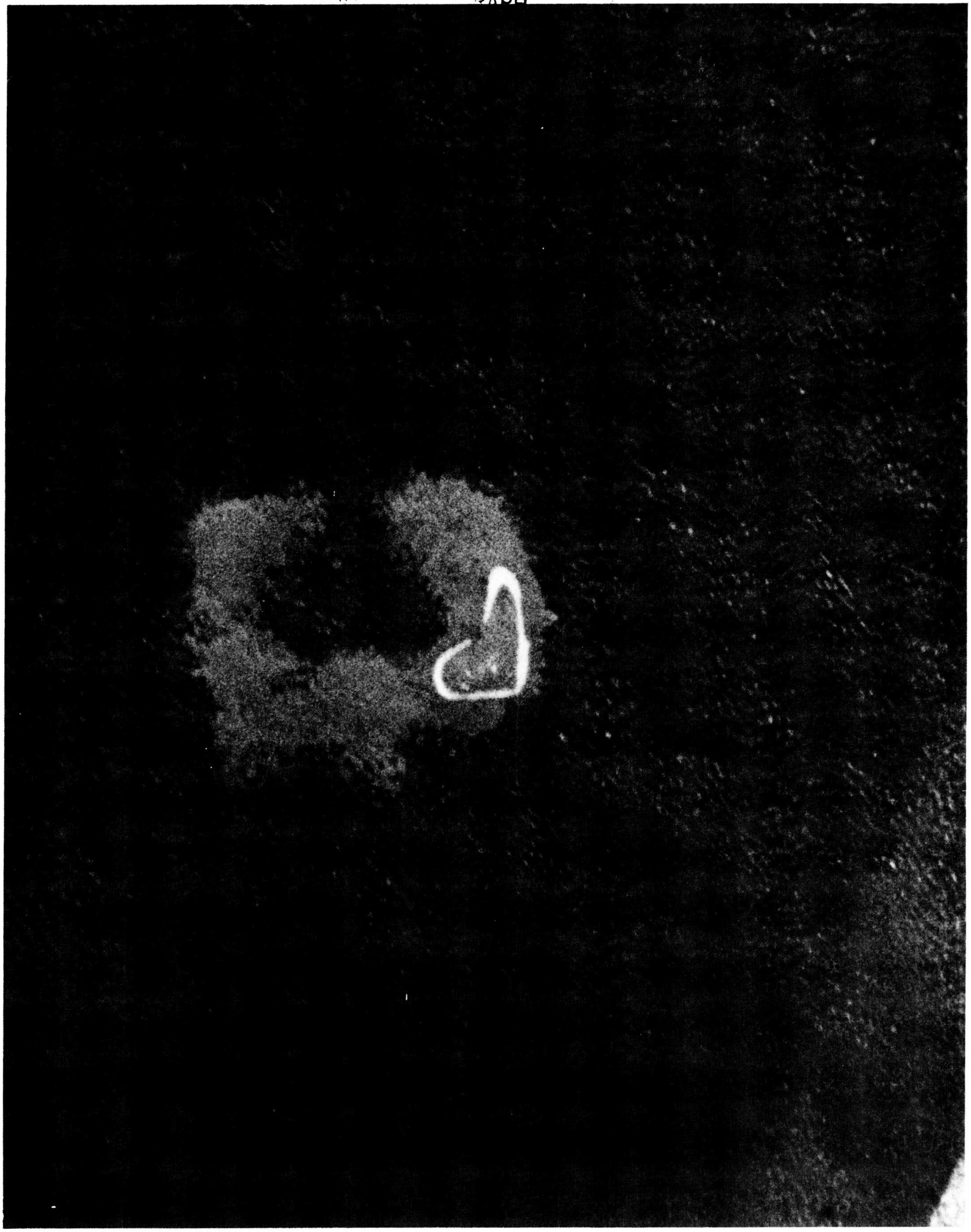


FROST SPOT ON TPS REPAIR NEAR AFT HARDPOINT CLOSEOUT AREA



ACREAGE FROST ON TPS REPAIR AREA AT APPROXIMATELY XT 1900 (ABOUT 4 FEET FORWARD OF THE -Y LONGERON)

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NO ANOMALIES VISIBLE ON TSM/ORBITER LH2 T-0 UMBILICAL.
DISCOLORED RCS COVER VISIBLE ON +Z SIDE OF LH OMS POD STINGER.

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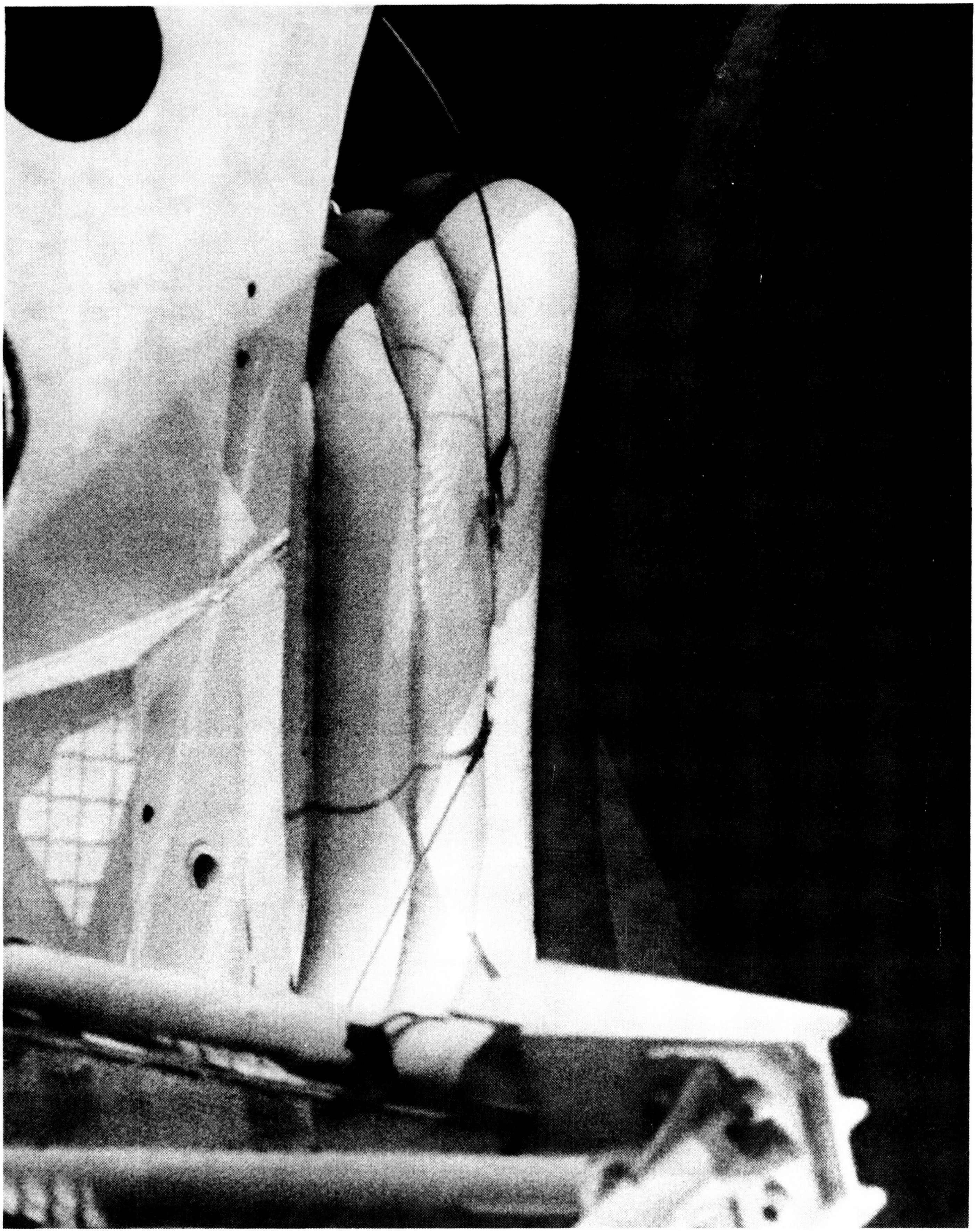
BLACK AND WHITE PHOTOGRAPH



NO LEAKAGE FROM SOUTH GOX VENT SEAL. GRID PATTERN ON ET FOOTPRINT IS VISIBLE INDICATING THAT SEAL IS POSITIONED HIGH.

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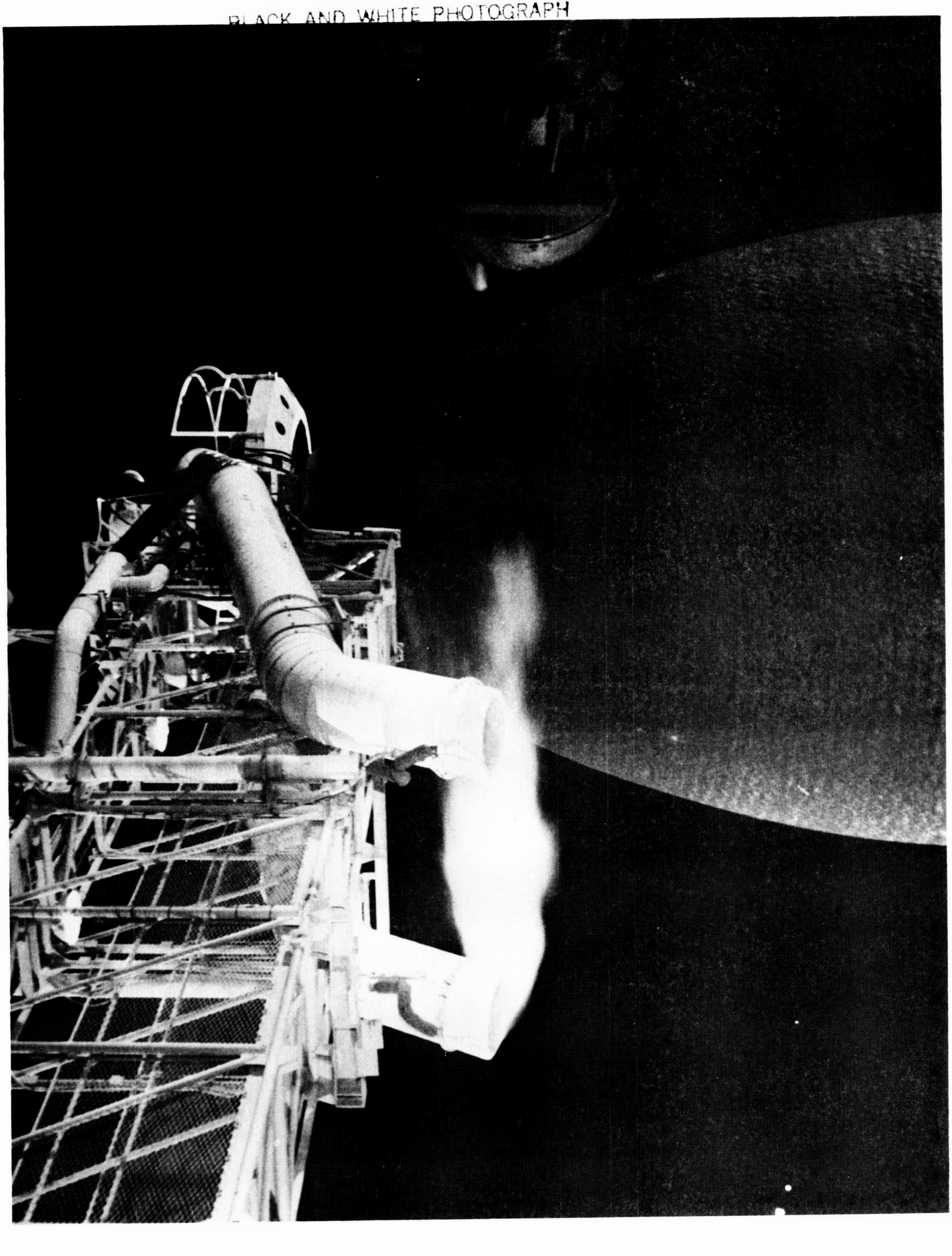

NO ICE/FROST ON -Y SIDE OF ET LO2 TANK OGIVE. THE NORTH GOX DUCT IS VENTING MUCH MORE THAN THE SOUTH DUCT.

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6.0 POST LAUNCH PAD DEBRIS INSPECTION

The post launch inspection of the pad and surrounding area began on 2 December 1988 from launch + 3 to 6 hours. The MLP, FSS, pad apron, and acreage areas were inspected. No significant flight hardware or TPS materials were found with the exception of two small pieces of Inconel foil insulation (which may have been closeout trimmings) from the SSMEs and the usual SRB throat plug material (foam and RTV). One Orbiter tile carrier panel Q-felt plug was found on the east side of the pad entrance. Many of these plugs have been recovered previously. Water trough material from the SRB exhaust holes were scattered throughout the field and on the pad apron.

SRB holddown post erosion was negligible for this launch. South holddown post shim material was intact, but had debonded from the shoe sidewall on holddown post # 1, 2, and 5. One small piece of sidewall material 4"x1" was missing from holddown post # 1 inboard upper shelf. No shrapnel from holddown post debris containers was found. All of the doghouse blast covers on the north holddown posts were in the closed position, exhibited no apparent damage, and did not appear to be missing any parts. The SRB aft skirt purge lines were in place and not damaged. The new SRB joint heater umbilicals showed no damage after separation. A large bracket for securing the sound suppression water troughs had separated from the water deluge pipe near holddown post # 3 and was found lying in the SRB flame trench. A 5′ X 2′ piece of fiberglas material from the facility was found on the south side of the pad apron. Several pieces of typical facility debris were found at the pad perimeter.

The GOX vent arm, OAA, and TSM′s showed signs of slight damage. The GH2 vent arm was latched on the fourth tooth of the latching mechanism. No loose cables dangled from the haunch.

All seven emergency egress baskets were secured on the FSS 195 foot level and exhibited no launch damage.

The new Shuttle Thermal Imager (STI) units located at Camera Site 2 and on the roof of the RSS sustained no launch damage and were operational after launch. Both housings were coated with SRB residue.

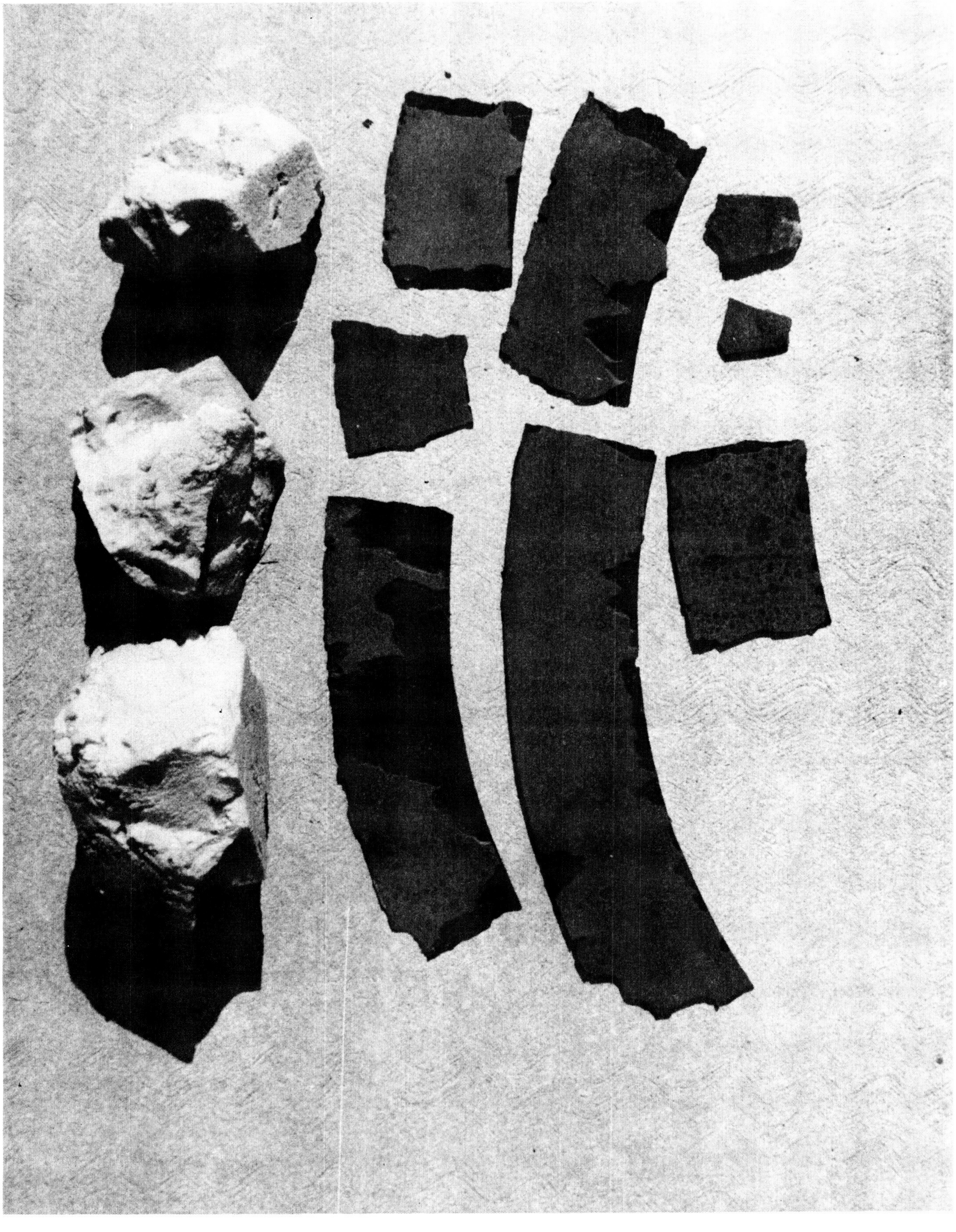
Overall there was very little damage to the Pad facility.

The debris inspection was expanded on 3 December 1988 to include areas outside the pad perimeter fence. Ground teams searched the beach, railroad tracks, and beach road from the northern KSC boundary to the Titan complex. The NASA helicopter was utilized to cover the water areas around the pad, the beach from Port Canaveral to a point 10 miles north of the pad, and ocean area under the flight path. No flight hardware or TPS material from the launch vehicle was found.

Due to the unidentified debris object observed in the vicinity of the RH SRB shortly after separation, inspections of the beach from the northern KSC boundary to the Titan complex were conducted for an additional 4 days in the event any potential debris may have washed ashore. Two pieces of suspect ET TPS were found. Subsequent lab analysis revealed the samples were not TPS from the Shuttle vehicle.

After landing, the Orbiter was found to have a severe amount of tile damage. This prompted additional inspections of the beach by ground and helicopter teams in an effort to recover debris material that may yield clues to source and cause. No SRB TPS material was recovered, but one piece of suspect ET TPS was found near New Smyrna Beach. Although it was similar to BX-250, lab analysis showed the sample was not TPS from the External Tank.

In summary, no TPS debris was found in the vicinity of Pad 39B. The vehicle was probably far enough down range to cause any pieces of debris to be carried north by Gulf Stream currents.



POST-LAUNCH SAMPLES OF SRB THROAT PLUG MATERIAL

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NORTH HOLDDOWN POST EXHIBITING MINIMAL POST LAUNCH DAMAGE. DOGHOUSE BLAST COVER CLOSED NOMINALLY.

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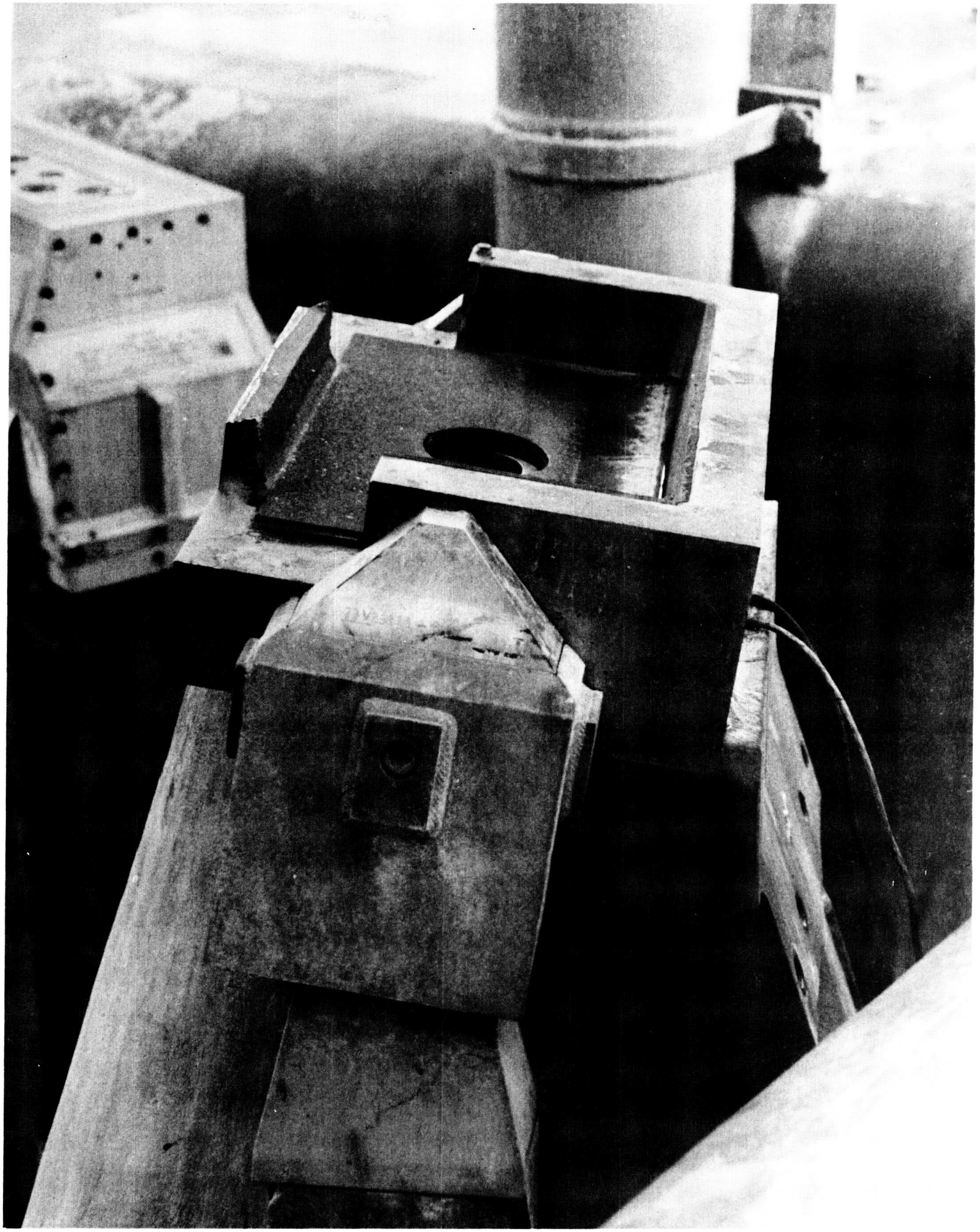

HOLDDOWN POST #5 (LH SRB SE CORNER) EXHIBITING NO POST LAUNCH DAMAGE. CORNER OF SHIM IS DEBONDED.

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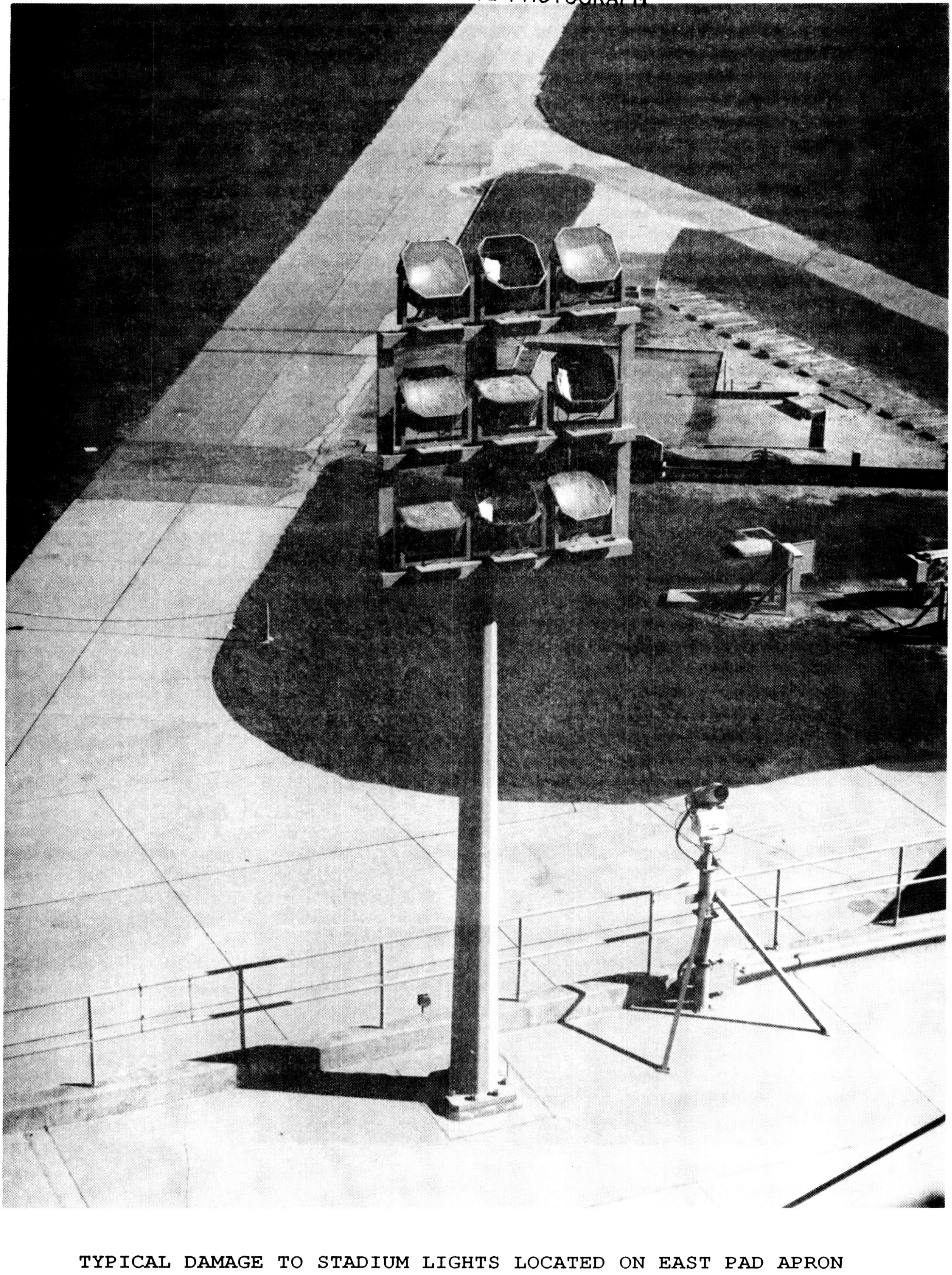


TYPICAL DAMAGE TO STADIUM LIGHTS LOCATED ON EAST PAD APRON

7.0 LAUNCH FILM SUMMARY/PROBLEM REPORT DISPOSITION

A total of 113 film and video data items, which included 39 videos, 52 16mm films, 14 35mm films, and 8 70mm films, were reviewed starting on Launch day.

No major vehicle damage or lost flight hardware was observed that would have affected the mission. However, a rectangular shaped, light colored object first appears near the RH OMS POD at 30 seconds MET and is visible against the Orbiter wing and fuselage for 7 frames before disappearing into the SRB plume. This object may be the carrier panel lost from the RH OMS POD during ascent. (Best views are on E-57, 58, 59 - less defined views on E-203, 216, 217).

During SSME ignition, burning hydrogen rises along side of SSME #3 and is consumed before reaching the Orbiter LO2 T-0 umbilical (E-17, E-19, OTV 170).

Nine tile shims are shaken loose and one gap filler left protruding from the inboard side of the RH RCS stinger during SSME ignition (E-17, 19, 23, 76).

SSME ignition causes a shower of ice/frost particles to fall from the ET/ORB umbilicals and ET feedline areas. Many particles 'brush' against the Orbiter inboard elevon, but no damage is visible. Two tile gap fillers are also shaken loose. (E-5, 6, 25).

Many film and video items record various amounts of flying debris. This debris is SRB throat plug material and shredded water troughs - an expected occurrence.

There were no major facility anomalies. No swing arms or other pad structures contacted the vehicle during liftoff.

SSME 'flashes' are visible early in flight at 18 through 22, 30, 38, and 42 seconds MET. These flashes are thought to be propulsion characteristics of the Shuttle main engines and have been seen on virtually all previous flights (E-52, 53, 54, 57, 58, 59, 214, 217, TV-4).

Many pieces of debris are visible during early ascent: 10 white objects 14 seconds MET below the RH wing, 1 white object 17 seconds MET near the RH wing, and at least 4 white objects 18-20 seconds MET in the vicinity of the RH wing tip and along the leading edge. Some of the debris can be identified as ice/frost from the umbilicals or RCS paper covers. Debris this early in flight is usually SSME nozzle frost, umbilical ice, and RCS paper covers, but other phenomenon, such as atmospheric condensation, SSME flashes, plume gas dynamics, and even film defects may appear as solid objects (E-52, 53, 54, 57, 58, 59, 202, 204, 207. 214, 216, and 217).

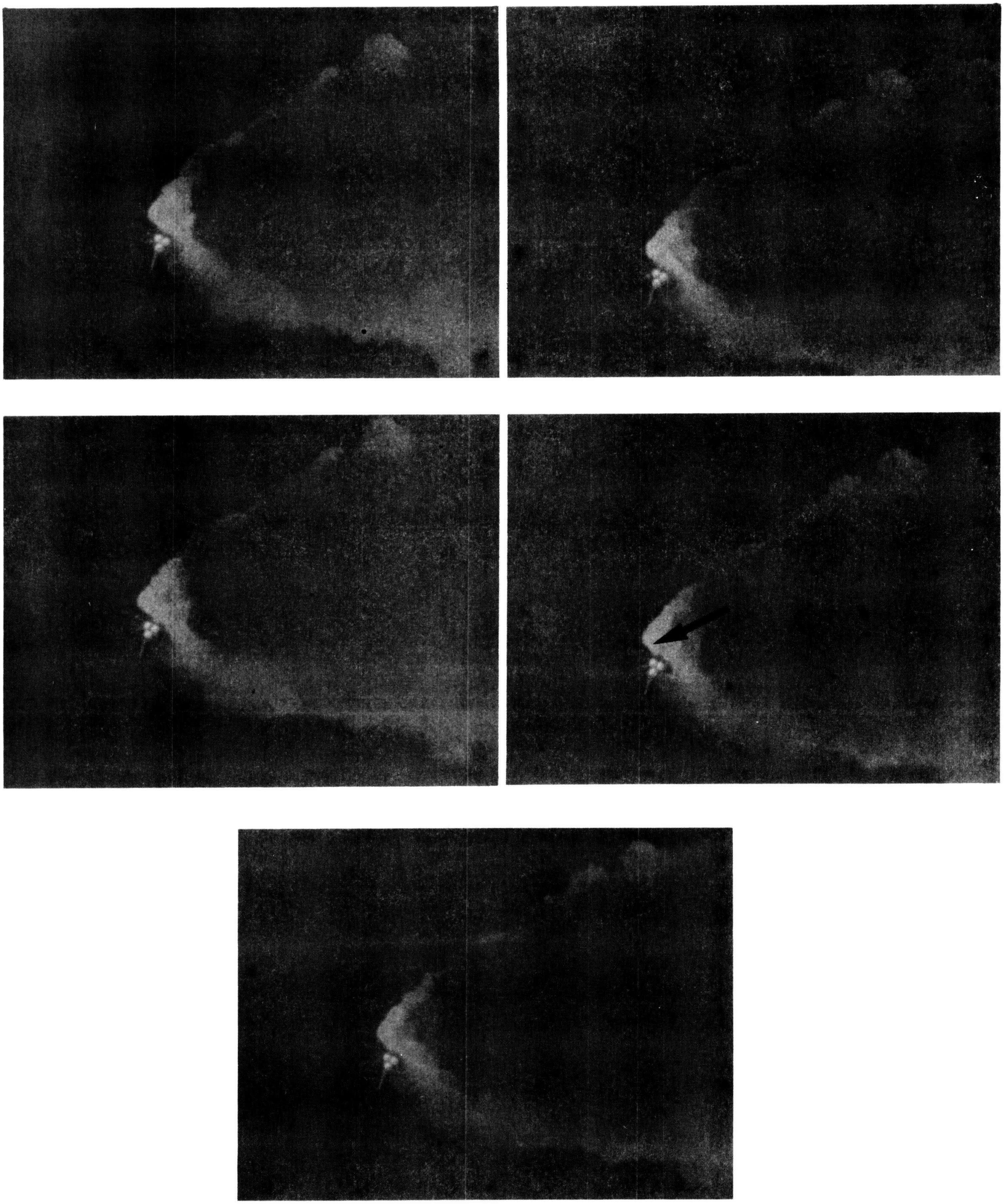
After SRB separation, a reddish-colored diffuse object with a major dimension of about 10 feet moves away from the boosters at 14:32:43.5 (129.5 seconds MET) and is visible for 2.8 seconds. The reddish/brown color is not usually associated with SRB slag and may be a piece of External Tank intertank foam from the -Z side of the vehicle (E-204). A review of photos taken of the External Tank by the flight crew shortly after ET separation reveal some divots in the +Z intertank TPS but no major components missing, such as the PAL ramp. In addition, two pieces of light colored debris were first visible in the vicinity of the RH SRB FWD skirt at 14:32:44 and 14:32:45 GMT (130 and 131 seconds MET), which is about 4 seconds after SRB separation. Trajectory analysis indicates the two pieces probably originated from the aft skirt area of the LH SRB and are most likely the 'slag' material that typically exits the SRB's after tailoff. Review of photo imagery from previous Shuttle flights clearly reveals solid material similar in size, shape, color, and luminosity coming out of the spent SRB nozzles (ET-206, ET-208).

Post flight computer analysis predicts a flight regime of high altitude, high vehicle speed (T+84 through 120 seconds MET) where ablator from the SRB nosecap and TPS from the External Tank caused the Orbiter tile damage. This event was not recorded conclusively on any film or video item.

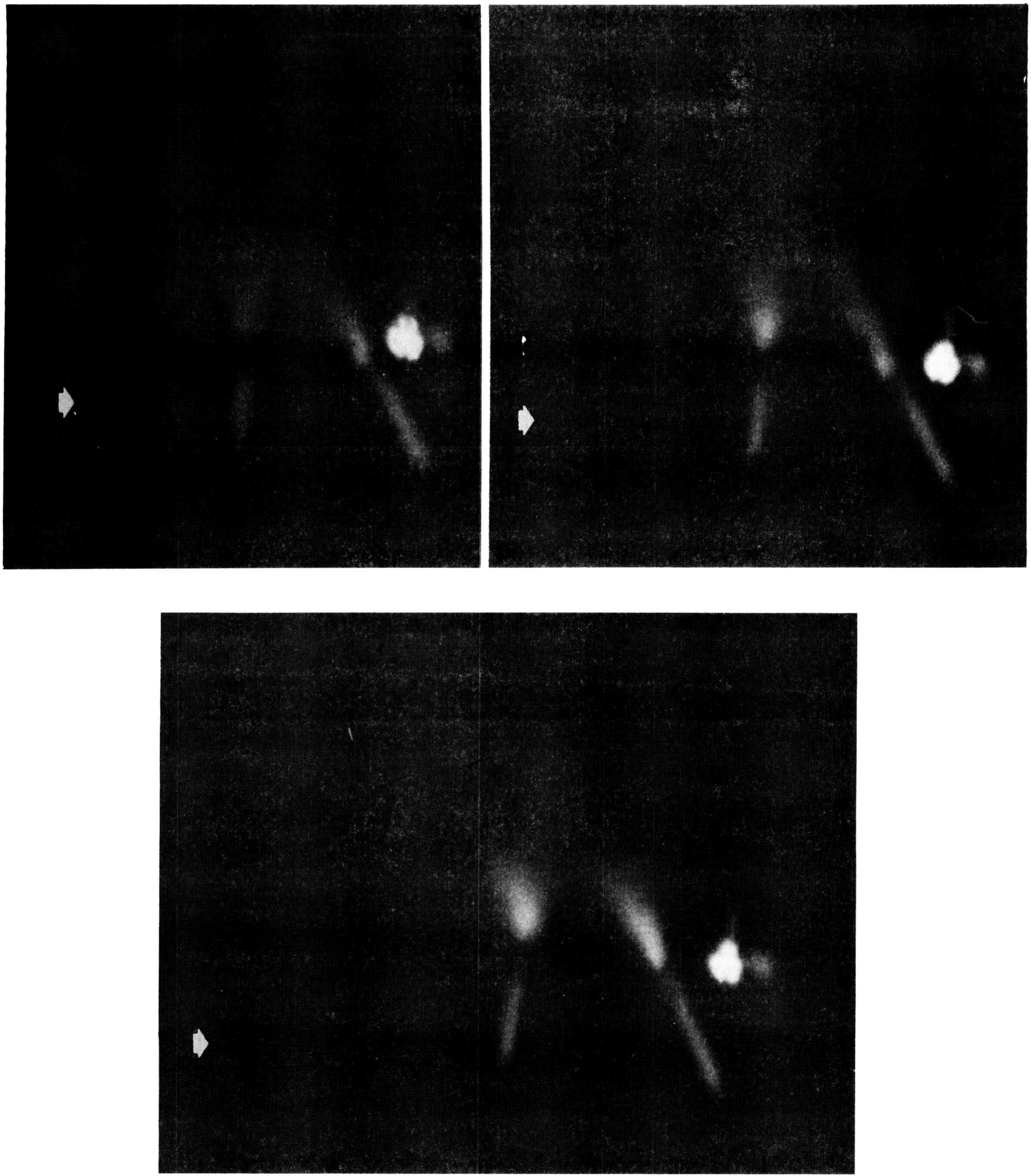
No PR's or IPR's were generated as a result of the launch film and video data review.

FILM ITEM E-6. ICE/FROST PARTICLES FALL FROM UMBILICALS AND "BRUSH" AGAINST RH INBOARD ELEVON. NO VISIBLE TPS DAMAGE.

C-2



FILM ITEM E-58. SUSPECT RH OMS POD CARRIER PANEL FALLLING FROM VEHICLE AT APPROXIMATELY T+30 SECONDS MET.



FILM ITEM E-204. REDDISH-COLORED DIFFUSE OBJECT MOVING AWAY FROM BOOSTERS AT T+129.5 SECONDS MET.

7.1 POST LAUNCH FILM DATA REVIEW

EX1 400 FPS 16mm	Camera is located on MLP deck south of RH SRB exhaust duct and looks north to view RH SRB Heater Umbilical during ignition and liftoff.

Focus : OK
F. O. V.: NO VIEW OF UMBILICAL OR SEPARATION UNTIL VEHICLE RISES
Exposure: UNDEREXPOSED

Comments: UNDEREXPOSED FILM AND AFT SKIRT INSTAFOAM PREVENT OBSERVATION OF JOINT HEATER UMBILICAL AT T-0. FIVE PIECES OF DEBRIS, CLOSEOUT MATERIAL AND INSTAFOAM OVERSPRAY, LOCATED BEHIND HDP DEBRIS CONTAINER ARE STIRRED UP BY SSME IGNITION. MORE DEBRIS IS DRAWN UPWARD OUT OF EXHAUST HOLE. HOLDDOWN POST HAUNCH TARGET COMES LOOSE AT SRB IGNITION. AS VEHICLE RISES, MORE PIECES OF ICE AND THROAT PLUG FALL INTO FIELD OF VIEW.

E-1 400 FPS 16mm	Camera is located on the NE corner of the MLP deck and views the lower ET, SRB's, and Orbiter.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: WATER SPRAY FROM FSS DELUGE SYSTEM IS BLOWN FROM NORTH TO SOUTH. WATER VAPOR FALLS FROM LH SRB STIFFENER RINGS. NO THERMAL CURTAIN TAPE IS LOOSE. AS WATER GEYSERS 20 FEET UPWARD FROM SOUND SUPPRESSION WATER TROUGHS, TWO PIECES OF DEBRIS RISE FROM EXHAUST HOLE AND FALL BACK INTO HOLE WITHOUT CONTACTING SRB. BOOSTER THROAT PLUG MATERIAL AND PIECES OF WATER TROUGH FLY OUTWARD AWAY FROM VEHICLE. ET/ORB UMBILICAL ICE IS SHAKEN LOOSE BY SSME IGNITION AND FIVE PIECES FALL TO MLP DECK NEAR LO2 TSM.

EX2 400 FPS 16mm	Camera is located on the MLP deck west of RH SRB exhaust duct and looks east to view SRB Heater Umbilical during ignition and liftoff.

Focus : OK
F. O. V.: TOO FAR LEFT
Exposure: UNDEREXPOSED

Comments: ICE FALLS CONTINUOUSLY AFTER SSME STARTUP AND SHATTERS ON MLP DECK. SOME PIECES HIT AFT SKIRT. DEBRIS IS DRAWN ALONG DECK SOUTHWARD TO SSME EXHAUST HOLE. JOINT HEATER UMBILICAL FALLS AT T-0, BUT SEPARATION IS NOMINAL. NO THERMAL CURTAIN ANOMALIES.

E-2
400 FPS
16mm

Camera is located on the SE corner of the MLP deck and views Orbiter SSME and OMS engine nozzles.

Focus : SOFT
F. O. V.: OK
Exposure: OK

Comments: FOUR PIECES OF DEBRIS, PROBABLY IGNITOR CAP COVERS, ORIGINATE FROM LO2 TSM AREA AND MOVE OUTWARD AWAY FROM VEHICLE BEFORE SSME IGNITION. RCS PAPER COVERS RUPTURE AT ENGINE STARTUP. A SHOWER OF ICE/FROST PARTICLES FALL FROM ET/ORB UMBILICALS AND IS BLOWN EASTWARD. NO SRM THERMAL CURTAIN TAPE COMES LOOSE. AS VEHICLE STARTS TO RISE, MANY PARTICLES FALL THROUGH FRAME MOVING GENERALLY TO THE SOUTH. PARTICLES MAY BE WATER OR FROST FROM FACILITY CRYO LINES BLOWN OFF OF FSS.

EX3
400 FPS
16mm

Camera is located on the MLP deck east of LH SRB exhaust duct and looks west to view SRB Heater Umbilical during ignition and liftoff.

Focus : OK
F. O. V.: OK
Exposure: UNDEREXPOSED

Comments: MLP DECK DEBRIS IS DRAWN ALONG DECK SOUTH TOWARD SSME EXHAUST HOLE. JOINT HEATER UMBILICAL APPEARS TO DROP EARLY, BUT SEPARATION LOOKS NOMINAL. SRB THROAT PLUG MATERIAL FALLS INTO FIELD OF VIEW AFTER T-0.

E-3
400 FPS
16mm

Camera is located on the SW corner of the MLP deck and views Orbiter SSME and OMS engine nozzles.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: SSME IGNITION APPEARS NORMAL. RCS PAPER COVERS RUPTURE AT SSME STARTUP. NO SRB THERMAL CURTAIN TAPE COMES LOOSE. AN RCS PAPER COVER FALLS FROM BEHIND SSME #1 AND PASSES IN FRONT OF SSME #3 BEFORE BEING OBSCURED BY TSM AS VEHICLE STARTS TO RISE. AS VEHICLE CLEARS FRAME, A PIECE OF DEBRIS FALLS NEAR LO2 TSM.

EX4
400 FPS
16mm

Camera is located on MLP deck south of LH SRB exhaust duct and looks north to view LH SRB Heater Umbilical during ignition and liftoff.

Focus : OK
F. O. V.: DOES NOT SHOW UMBILICAL OR SEPARATION UNTIL SRB RISES
Exposure: UNDEREXPOSED

Comments: A SMALL PARTICLE EXITS THE DEBRIS BLAST CONTAINER AREA AT SSME IGNITION. NUMEROUS PIECES OF THROAT PLUG MATERIAL APPEAR AT SRM IGNITION. WATER TROUGH MATERIAL ENTERS VIEW WELL AFTER THE VEHICLE CLEARS THE FRAME.

E-4
400 FPS
16mm

Camera is located on the NW corner of the MLP deck and views lower ET, SRB's, and Orbiter.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: ALL PROPULSION SYSTEMS APPEAR NOMINAL. NO TAPE IS LOOSE ON SRB THERMAL CURTAINS. WATER FROM SRB SOUND SUPPRESSION WATER TROUGHS GEYSERS 20 FEET. AS VEHICLE RISES, LARGE QUANTITIES OF WATER DELUGE SPRAY AND FROST PARTICLES TRAVEL IN AN EASTERLY DIRECTION. VEHICLE CLEARS FRAME AS SRB THROAT PLUG AND WATER TROUGH MATERIAL ARE BLOWN TOWARD CAMERA.

E-5
400 FPS
16mm

Camera is located on the east side of the MLP deck and views the Orbiter RH wing, body flap, and lower ET/SRB.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: A SHOWER OF ICE/FROST PARTICLES IS SHAKEN LOOSE FROM THE ET/ORB LO2 UMBILICAL AT SSME IGNITION. THE PARTICLES ARE BLOWN IN A SOUTHWESTERLY DIRECTION. SOME CONTACT THE INBOARD ELEVON, BUT NO DAMAGE IS VISIBLE. NO VEHICLE ANOMALIES.

E-6
200 FPS
16mm

Camera is located on the east side of the MLP deck and views the RH lower Orbiter wing, body flap, ET lower LOX feedline,and ET/Orbiter umbilical area.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: SSME IGNITION SHAKES LOOSE A SHOWER OF ICE/FROST PARTICLES FROM THE ET/ORB UMBILICALS AND ET FEEDLINE AREAS. MANY PARTICLES 'BRUSH' AGAINST THE ORBITER INBOARD ELEVON, BUT NO VISIBLE DAMAGE IS SUSTAINED. TWO TILE GAP FILLERS ARE ALSO SHAKEN LOOSE. A WHITE, RIGID, TRIANGULAR SHAPED OBJECT ENTERS FIELD OF VIEW FROM THE RIGHT AND TRAVELS SOUTH. IT DOES NOT APPEAR TO BE AN ORBITER WHITE TILE. ELEVONS MOVE SLIGHTLY DURING LIFTOFF.

E-7
400 FPS
16mm

Camera is located on the MLP deck and views the RH SRB northeast holddown post (HDP 4).

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: HPU EXHAUST IS VISIBLE NEAR LEFT SIDE OF FRAME PRIOR TO T-0. SRB THROAT PLUG MATERIAL IS THROWN UPWARD BY BACKFLOW OF EXHAUST. HOLDDOWN POST DOGHOUSE BLAST COVER CLOSES BEFORE NOZZLE EXTENSION PASSES (NOMINAL). EPON SHIM IS STILL BONDED TO AFT SKIRT FOOT AND ONE FRAGMENT APPEARS TO DROP FROM THE HOLE IN THE AFT SKIRT FOOT.

E-8
400 FPS
16mm

Camera is located on the MLP deck and views the RH SRB southeast holddown post (HDP 2).

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: NUMEROUS PIECES OF ICE FALL TO MLP DECK, SHATTER, AND ARE PULLED INTO SRB EXHAUST HOLE BY BOOSTER ASPIRATION. ICE PROBABLY ORIGINATES FROM ET/ORB LH2 UMBILICAL. NO NSI OR FRANGIBLE NUT FRAGMENTS DROP FROM HOLE IN AFT SKIRT.

E-9
400 FPS
16mm

Camera is located on the MLP deck and views the RH SRB southwest holddown post (HDP 1).

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: AT LEAST SIX SMALL FROST PARTICLES FROM ET/ORB UMBILICALS AND IGNITOR SPARKS LAND ON MLP DECK AFTER SSME IGNITION. A TARGET ON THE SRB HOLDDOWN POST HAUNCH COMES LOOSE AT SRB IGNITION. NO SRB THERMAL CURTAIN TAPE COMES LOOSE DURING LIFTOFF. NO PIECES OF FRANGIBLE NUT OR NSI ARE OBSERVED DROPPING FROM HOLE IN AFT SKIRT FOOT. FOUR SMALL PIECES OF INSTAFOAM OVERSPRAY COME LOOSE AS VEHICLE RISES.

E-10
400 FPS
16mm

Camera is located on the MLP deck and views the RH SRB northwest holddown post (HDP 3).

Focus : OK
F. O. V.: OK
Exposure: UNDEREXPOSED

Comments: HOLDDOWN POST HAUNCH TARGET COMES OFF AT T-0 AND FALLS INTO EXHAUST HOLE. AS VEHICLE STARTS TO LIFT OFF, BACKFLOW OF EXHAUST GAS RISES ALONG SIDE HDP #3 AND IMPINGES ON AFT SKIRT INSTAFOAM. HOLDDOWN POST DOGHOUSE BLAST COVER CLOSES JUST BEFORE SRB NOZZLE EXTENSION PASSES. NO NSI OR FRANGIBLE NUT FRAGMENTS DROP FROM AFT SKIRT. AFTER VEHICLE CLEARS FRAME, THROAT PLUG AND WATER TROUGH MATERIAL ARE THROWN TOWARD CAMERA.

E-11
400 FPS
16mm

Camera is located on the MLP deck and views the LH SRB northeast holddown post (HDP 7).

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: MLP DECK DEBRIS IS DRAWN TOWARD SSME EXHAUST HOLE PRIOR TO T-0. NO NSI OR FRANGIBLE NUT FRAGMENTS DROP FROM HOLE IN AFT SKIRT FOOT. HOLDDOWN POST DOGHOUSE BLAST COVER DOES NOT CLOSE BEFORE SRB NOZZLE EXTENSION PASSES. NO THERMAL CURTAIN ANOMALIES.

E-12
400 FPS
16mm

Camera is located on the MLP deck and views the LH SRB southeast holddown post (HDP 5).

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: SMALL PIECES OF THROAT PLUG MATERIAL AND FROST PARTICLES ARE BLOWN THROUGH FRAME AT SRB IGNITION. NO TAPE ON SRB THERMAL CURTAIN HAS COME LOOSE. NO FRAGMENTS FROM FRANGIBLE NUT OR NSI ARE OBSERVED DROPPING FROM HOLE IN AFT SKIRT FOOT.

E-13
400 FPS
16mm

Camera is located on the MLP deck and views the LH SRB southwest holddown post (HDP 6).

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: CLEAN SEPARATION OF AFT SKIRT FROM HOLDDOWN POST. NO NSI OR FRANGIBLE NUT FRAGMENTS DROP FROM HOLE IN AFT SKIRT. NO LOOSE TAPE ON THERMAL CURTAINS AND NO SRB ANOMALIES. ONE PIECE OF ICE ENTERS TOP CENTER OF FRAME AND MOVES SOUTH.

E-14
400 FPS
16mm

Camera is located on the MLP deck and views the LH SRB northwest holddown post (HDP 8).

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: DEBRIS PARTICLES ARE DRAWN INTO EXHAUST HOLE BY SRB ASPIRATION. HOLDDOWN POST DOGHOUSE BLAST COVER JUST BARELY CLOSES BEFORE NOZZLE EXTENSION PASSES. NO FRAGMENTS FALL FROM AFT SKIRT FOOT. INSTAFOAM OUTGAS PRODUCTS BURN BRIEFLY NEAR AFT SKIRT FOOT AS BOOSTER BEGINS TO ASCEND. SMALL PIECES OF INSTAFOAM FALL FROM AFT SKIRT DURING LIFT OFF. AS SRB CLEARS FRAME, THROAT PLUG AND WATER TROUGH MATERIAL ARE THROWN TOWARD CAMERA.

E-15 400 FPS 16mm	Camera is located on the MLP deck and views the RH SRB skirt, sound suppression water troughs, and RH lower Orbiter body flap.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: EXHAUST FROM SRB HYDRAULIC POWER UNIT IS VISIBLE ON EAST SIDE OF AFT SKIRT PRIOR TO T-0. ICE FALLS FROM ET/ORB LO2 UMBILICAL. TARGET ON HOLDDOWN POST #3 COMES LOOSE AT SRB IGNITION. VIEW IS MOMENTARILY OBSCURED BY WATER GEYSER FROM WATER TROUGHS AND SEVERAL PIECES OF DEBRIS RISE OUT OF EXHAUST HOLE. ONE PIECE OF THERMAL CURTAIN TAPE HAS COME LOOSE. HOLDDOWN POST DOGHOUSE BLAST COVERS CLOSE SIMULTANEOUSLY BUT APPEAR TO BE SLOW. BACKFLOW OF EXHAUST GASES IMPINGE ON AFT SKIRT INSTAFOAM NEAR HOLDDOWN POST #3. NO NSI OR FRANGIBLE NUT FRAGMENTS ARE OBSERVED DROPPING FROM AFT SKIRT FOOT HOLES. EPOXY SHIMS REMAIN ATTACHED TO AFT SKIRT. AFTER VEHICLE CLEARS FRAME, SIX PIECES OF SILICONE DECK PAINT MOVE THROUGH FRAME.

E-16 400 FPS 16mm	Camera is located on the MLP deck and views the LH SRB skirt, sound suppression water troughs, and LH lower Orbiter body flap.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: WATER GEYSER FROM SRB SOUND SUPPRESSION WATER TROUGHS OBSCURES INITIAL MOVEMENT OF VEHICLE. BOTH HOLDDOWN POST DOGHOUSE BLAST COVERS CLOSE, BUT APPEAR TO BE SLOW. SOME BURNING OF THE INSTAFOAM OUTGAS PRODUCTS OCCURS NEAR HOLDDOWN POST #8. NO NSI OR FRANGIBLE NUT FRAGMENTS ARE VISIBLE DROPPING FROM FOOT HOLES IN AFT SKIRT. EPOXY SHIMS REMAIN ATTACHED TO AFT SKIRT.

E-17 400 FPS 16mm	Camera is located on the MLP deck and views the -Z side of the LO2 T-0 Umbilical and TSM.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: BURNING HYDROGEN RISES ALONG SIDE OF SSME #3. RCS PAPER COVERS RUPTURE AND 10 TILE SHIMS FROM INBOARD SIDE OF RCS STINGER FALL AT SSME IGNITION. NUMEROUS PIECES OF ICE FROM ET/ORB UMBILICALS CROSS FIELD OF VIEW MOVING EAST - NO HITS ON BODY FLAP ARE VISIBLE. ORBITER LO2 T-0 UMBILICAL RETRACTION IS NOMINAL. NO SSME ANOMALIES.

E-18
400 FPS
16mm

Camera is located on the MLP deck and views the -Z side of the LH2 T-0 umbilical and TSM.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: RCS PAPER COVERS RUPTURE AT IGNITION. FROST PARTICLES FALL FROM UMBILICAL. VAPOR VENTS FROM INBOARD SIDE OF OMS POD. SEPARATION AND RETRACTION OF ORBITER LH2 T-0 UMBILICAL IS NOMINAL. PURGE BARRIER IS CAUGHT IN TSM DOOR NEAR RCS STINGER. TWO TILES ARE CHIPPED ON AFT SIDE OF RCS STINGER FROM SSME ACOUSTICS.

E-19
400 FPS
16mm

Camera is located on the SE side of the MLP deck and views the SSME/OMS nozzles and Orbiter aft heat shield area.

Focus : OK
F. O. V.: OK
Exposure: OK
Comments: RCS PAPER COVERS RUPTURE AT SSME IGNITION. HYDROGEN FIRE RISES ALONGSIDE OF SSME #3 NOZZLE. SSME IGNITION APPEARS NORMAL. OMS NOZZLE MOVES ONLY SLIGHTLY WITH ENGINE STARTUP. AT LEAST NINE SHIMS DROP FROM TILES BEHIND RH RCS STINGER AND ONE GAP FILLER IS LEFT PROTRUDING. SEVERAL RCS PAPER COVERS FALL AT THIS SAME TIME FRAME. FROST HAS FORMED ON THE SSME #2 ENGINE MOUNTED HEAT SHIELD. ICE FALLS FROM LO2 T-0 UMBILICAL. AN RCS PAPER COVER COMES INTO VIEW FROM BEHIND SSME #1. PURGE BARRIER MATERIAL WAS CAUGHT IN THE TSM DOOR DURING CLOSURE.

E-20
400 FPS
16mm

Camera is located on the SW side of the MLP deck and views the SSME/OMS nozzles and Orbiter aft heat shield area.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: RCS PAPER COVERS ARE RUPTURED AND THREE TILES ARE CHIPPED ON THE LH RCS STINGER BY SSME IGNITION ACOUSTICS. SSME STARTUP APPEARS NORMAL AND THE LH OMS NOZZLE SHOWS VERY LITTLE MOVEMENT. HYDROGEN FIRE RISES ALONG SIDE LH RCS STINGER. TWO DARK PIECES OF DEBRIS ORIGINATE FROM FSS AND CROSS FIELD OF VIEW. A LIGHT COLORED OBJECT FALLS BETWEEN SSME NOZZLES.

E-21
200 FPS
16mm

Camera is located inside the LO2 TSM and views the disconnection of the T-0 umbilical.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: T-0 CARRIER PLATE RETRACTION IS NORMAL. NO EVIDENCE OF BURNING HYDROGEN FROM SSME #3 IN AREA OF T-0 UMBILICAL.

E-22
200 FPS
16mm

Camera is located inside the LH2 TSM and views the disconnection of the T-0 umbilical.

Focus : OK
F. O. V.: OK
Exposure: OK, BUT CAMERA LIGHT GOES OFF EARLY

Comments: PURGE BARRIER COMES PARTIALLY LOOSE AT SSME IGNITION. T-0 CARRIER PLATE RETRACTION APPEARS NORMAL.

E-23
400 FPS
16mm

Camera is located on the MLP deck and views the RH OMS engine nozzle.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: FREE HYDROGEN IGNITES AND QUICKLY DISSIPATES. RCS PAPER COVERS RUPTURE AT SSME IGNITION. NINE TILE SHIMS ARE SHAKEN LOOSE AND ONE GAP FILLER PROTRUDES FROM THE INBOARD SIDE OF THE RCS STINGER. OMS NOZZLE VIBRATION AND MOVEMENT IS MINIMAL. RETRACTION OF LO2 T-0 UMBILICAL CARRIER PLATE APPEARS NORMAL. A PIECE OF ICE IS VISIBLE FALLING PAST ELEVON AS VEHICLE RISES ABOVE TSM.

E-24 400 FPS 16mm	Camera is located on the MLP deck and views the LH OMS engine nozzle.

Focus : OK
F. O. V.: LOW
Exposure: OK

Comments: FREE HYDROGEN IGNITES AND PASSES CAMERA BEFORE DISSIPATING. RCS PAPER COVERS RUPTURE AT SSME IGNITION. OMS NOZZLE EXHIBITS MINIMAL VIBRATION AND MOVEMENT. RETRACTION OF ORBITER LH2 T-0 UMBILICAL CARRIER PLATE APPEARS NORMAL.

E-25 400 FPS 16mm	Camera is located on the east side of the MLP and views between Orbiter and ET/SRB during liftoff.

Focus : OK
F. O. V.: OK
Exposure: UNDEREXPOSED

Comments: ELEVONS MOVE SLIGHTLY AT SSME IGNITION. ICE FALLS FROM ET/ORB UMBILICALS AND IS BLOWN EASTWARD. THREE PIECES OF THIS ICE CONTACT THE ORBITER WING INBOARD ELEVON, BUT NO DAMAGE IS VISIBLE. SMALL PIECES OF SRB THROAT PLUG MATERIAL ARE PROPELLED UPWARD BY EXHAUST BACKFLOW AND SIX PARTICLES BOUNCE OFF OF ORBITER WING. WATER FROM SRB STIFFENER RINGS VAPORIZES. ONE PIECE OF SRB THERMAL CURTAIN TAPE COMES LOOSE DURING LIFTOFF.

E-26 400 FPS 16mm	Camera is located on the west side of the MLP and views between Orbiter and ET/SRB during liftoff.

Focus : OK
F. O. V.: OK
Exposure: DARK

Comments: WATER SPRAYS FROM ET INTERTANK ACCESS STRUCTURE. LH WING ELEVONS MOVE AT LIFTOFF. ET GH2 VENT LINE DROPS AND LATCHES NORMALLY.

E-27 400 FPS 16mm	Camera is located on the MLP deck and views RH SRB northwest holddown post (HDP M-3) blast cover.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: INITIAL SURGE OF EXHAUST GAS CAUSES PIECES OF SRB THROAT PLUG MATERIAL TO BE THROWN UPWARD. WATER FROM THE SOUND SUPPRESSION WATER TROUGHS GEYSERS. ONE PIECE OF THERMAL CURTAIN TAPE IS LOOSE. HOLDDOWN POST DOGHOUSE BLAST COVER CLOSURE IS NORMAL. UNKNOWN PIECE OF DEBRIS IS VISIBLE IN AFT SKIRT FOOT #4 BEHIND DEBRIS CONTAINMENT PLUNGER. PIECES OF THROAT PLUG AND WATER TROUGH MATERIAL CONTINUE TO FLY THROUGH FIELD OF VIEW.

E-28 400 FPS 16mm	Camera is located on the MLP deck and views LH SRB northeast holddown post (HDP M-7) blast cover.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: ICE APPEARS FROM BEHIND RH SRB AND FALLS TO DECK. AS VEHICLE STARTS TO RISE, SMALL RIGID PIECE OF DEBRIS IS VISIBLE UNDER AFT SKIRT FOOT #8. INSTAFOAM OUTGAS PRODUCTS BURN BRIEFLY IN THIS SAME AREA. HOLDDOWN POST DOGHOUSE BLAST COVERS MAY NOT BE COMPLETELY CLOSED AS SRB NOZZLE EXTENSION PASSES BY.

E-30 400 FPS 16mm	Camera is located on the FSS 195 foot level and views LH SRB and sound suppression water troughs.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: FACILITY DELUGE WATER AND PARTICLES OF FROST MOVE TOWARD VEHICLE FROM FSS PRIOR TO T-0. SOME PIECES OF GUCP FROST FALL PAST LH SRB. NO SRB ANOMALIES VISIBLE AS BOOSTER CLEARS FRAME.

E-31 100 FPS 16mm	Camera is located on the FSS 95 foot level and views the LH Orbiter wing, body flap, and ET/Orbiter LH2 umbilical area.

Focus : OK
F. O. V.: OK
Exposure: UNDEREXPOSED

Comments: WATER DELUGE OBSTRUCTS DETAIL. ICE FALLS FROM ET/ORB UMBILICALS AT SSME IGNITION. ELEVONS MOVE AT LIFTOFF. NO VEHICLE ANOMALIES. AS VEHICLE RISES, A PIECE OF DEBRIS ENTERS FIELD OF VIEW FROM THE LEFT AND MOVES DOWNWARD.

E-33 400 FPS 16mm	Camera is located on the FSS 235 foot level and views the ET GH2 vent line and GUCP.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: ICE/FROST ACCUMULATION ON +Z SIDE OF GUCP. SEPARATION IS NORMAL AND SOME ICE PARTICLES FALL AWAY. FROST IS LEFT ON THE UNINSULATED BOTTOM AND SIDES OF THE ET GUCP PLATE. NO TPS PULLED LOOSE AT SEPARATION. SRB IS STREAKED BY WATER DELUGE FROM THE ET INTERTANK ACCESS STRUCTURE, BUT THE LH BOOSTER EXHIBITS NO ANOMALIES WHILE PASSING THROUGH THE FIELD OF VIEW.

E-34 200 FPS 16mm	Camera is located on FSS at 255 foot level and views upper Orbiter tile surfaces.

Focus : OK
F. O. V.: OK
Exposure: DARK

Comments: VIEW OBSCURED BY GREAT AMOUNT OF FACILITY DELUGE WATER. NO ORBITER TILE OR SRB DFI CLOSEOUT ANOMALIES. LH OMS POD LEADING EDGE TILES ARE UNDAMAGED.

E-35 200 FPS 16mm	Camera is located on the FSS 255 foot level and views the mid-Orbiter/ET/SRB area.

Focus : SOFT
F. O. V.: OK
Exposure: DARK

Comments: VIEW OBSCURED BY GREAT AMOUNT OF FACILITY DELUGE WATER. NO ORBITER TILE OR SRB DFI CLOSEOUT ANOMALIES. LH OMS POD LEADING EDGE TILES ARE UNDAMAGED. GH2 VENT ARM DROPS NORMALLY.

E-36 200 FPS 16mm	Camera is located on the FSS 255 foot level and views lower Orbiter, ET, SRB's, and water trough.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: NO ORBITER TILE OR SRB ANOMALIES. RETRACTION OF ORBITER LH2 T-0 UMBILICAL IS NORMAL.

E-39 200 FPS 16mm	Camera is located on the FSS 185 foot level and views GH2 vent line latchback.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: CAMERA STARTED LATE. VENT LINE IS ALREADY CAPTURED AND LATCHED.

E-40 200 FPS 16mm	Camera is located on the FSS 275 foot level and views the ET ogive, SRB nosecone, and Orbiter tiled surfaces.

Focus : OK
F. O. V.: PARTIALLY OBSCURED BY OTV CAMERA
Exposure: OK

Comments: TWANG EFFECT PLAINLY SEEN. WATER PARTIALLY OBSCURES VIEW. LARGE WATER DROPLETS WHICH APPEAR SIMILAR TO ICE FALL FROM THE WATER DELUGE SYSTEM. ET HYDROGEN DETECTION BUTCHER PAPER STILL ATTACHED. NO ET OR ORBITER ANOMALIES OBSERVED. AFTER VEHICLE CLEARS TOWER SMALL PIECES OF DEBRIS SEEN FLYING AROUND. VEHICLE MOVES NORTH APPROXIMATELY 15 FEET. ONE OF THE LIGHT CABLES GOING TO OTV CAMERA 104 HIT AFTER VEHICLE CLEARS TOWER.

E-41 200 FPS 16mm	Camera is located on the FSS 255 foot level and views the GH2 vent line during rotation. Also shows clearance between structure and SRB aft skirt.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: WATER DELUGE SPRAYS SOUTHWARD FROM ET INTERTANK ACCESS STRUCTURE. GH2 VENT LINE DISCONNECT AND LATCHBACK IS NOMINAL. VENT LINE DID NOT CONTACT LH SRB. NO VEHICLE ANOMALIES. NUMEROUS PIECES OF FACILITY DEBRIS PASS THROUGH FIELD OF VIEW AFTER VEHICLE CLEARS TOWER. A PARTICULARLY LARGE PIECE (FRAME 2910) MAY ORIGINATE FROM FSS 275 FOOT LEVEL OR GOX VENT ARM.

E-42 200 FPS 16mm	Camera is located on the FSS 185 foot level and views the GH2 vent line drop, deceleration, and latchback.

Focus : OK
F. O. V.: OK
Exposure: UNDEREXPOSED

Comments: GH2 VENT ARM RETRACTION AND LATCHBACK IS NORMAL. VEHICLE IS NOT IN VIEW DURING LIFTOFF. DEBRIS PASSES THROUGH FIELD OF VIEW WELL AFTER VEHICLE CLEARS TOWER.

E-43 100 FPS 16mm	Camera is located on pad surface and views sound suppression water flow distribution beneath MLP.

Focus : SOFT
F. O. V.: OK
Exposure: OK

Comments: NO UNUSUAL AMOUNTS OF BURNING HYDROGEN ARE VISIBLE UNDER MLP.

E-44
200 FPS
16mm

Camera is located on the FSS 155 foot level and views the LH OMS Pod leading edge tiles during ignition and liftoff.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: TPS IS INTACT AND UNDAMAGED AS OMS POD PASSES THROUGH FIELD OF VIEW. LH2 T-0 UMBILICAL RETRACTION IS NORMAL.

E-48
200 FPS
16mm

Camera is located on the FSS 215 foot level (ET Intertank access arm structure) and views the GH2 vent line during GUCP disconnection, rotation, and latchback

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: GUCP DISCONNECT AND GH2 VENT ARM RETRACTION IS NOMINAL. VENT LINE DOES NOT CONTACT LH SRB. ICE/FROST PARTICLES FALL AS GUCP DISCONNECTS. VEHICLE 'WALKS' NORTH DURING LIFTOFF, BUT NO ANOMALIES ARE OBSERVED. DELUGE WATER AND CONDENSATE FALLS FROM SRB ETA RING.

E-50
200 FPS
16mm

Camera is located at camera site 1 at NE pad perimeter and views entire GH2 vent line and GUCP during rotation and latchback.

Focus : OK
F. O. V.: TOO FAR RIGHT
Exposure: OK

Comments: RUSTY DELUGE WATER SPRAYS FROM ET INTERTANK ACCESS STRUCTURE. GUCP DISCONNECT AND GH2 VENT ARM RETRACTION/LATCHBACK IS NORMAL. VENT LINE DID NOT CONTACT LH SRB. AS VEHICLE CLEARS FRAME, A BIRD CROSSES FIELD OF VIEW HEADING EAST AWAY FROM VEHICLE.

E-52 96 FPS 35mm	Camera is located at camera site 2 on the east pad perimeter. Remote tracking of lower one-third of launch vehicle from ignition to 1200 feet.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: WATER DELUGE SPRAYS OFF THE ET INTERTANK ACCESS STRUCTURE. A SHOWER OF ICE/FROST PARTICLES FALLS FROM THE ET/ORB UMBILICALS AT IGNITION. THE GH2 VENT LINE RETRACTS AND LATCHES PROPERLY. WATER VAPOR FROM THE SRB STIFFENER RINGS VAPORIZES. TWO PIECES OF LH2 UMBILICAL ICE FALL JUST BEFORE ROLL PROGRAM. THREE RCS PAPER COVERS FALL PRIOR TO AND A 4TH JUST AFTER ROLL MANEUVER. SOME LIGHT COLORED DEBRIS CONTINUES TO BE VISIBLE IN THE VICINITY OF THE RH WING UP THROUGH 18 SECONDS MET. THE SSME PLUME EXHIBITS FLASHES SIMILAR TO THAT SEEN DURING STS-26R.

E-53 96 FPS 35mm	Camera is located at camera site 2 on the east pad perimeter. Remote tracking of middle one-third of launch vehicle from ignition to 1200 feet.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: WATER VAPORIZES ON ET AFT DOME. SSME FROST FALLS FROM -Y SIDE OF SSME #1 AND RCS PAPER COVER FALLS FROM +Y STINGER AFTER VEHICLE CLEARS TOWER. DURING ROLL MANEUVER, ONE OBJECT APPEARS FROM REGION OF LH OMS POD, THREE OBJECTS FALL FROM TOP-SIDE REGION OF LH INBOARD ELEVON, AND ANOTHER OBJECT IS VISIBLE IN AREA OF RH OMS POD. STILL ANOTHER FALLS FROM UNDERSIDE OF LH INBOARD ELEVON (5-18 SECONDS MET). DEBRIS THIS EARLY IN FLIGHT IS USUALLY MORE UMBILICAL ICE/FROST AND RCS PAPER COVERS.

E-54 96 FPS 35mm	Camera is located at camera site 2 on the east pad perimeter. Remote tracking of upper one-third of launch vehicle from ignition to 1200 feet.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: WATER VAPORIZES ON ET AFT DOME. DURING ROLL MANEUVER, AN OBJECT FALLS FROM REGION OF LH OMS POD, THREE OBJECTS APPEAR FROM UPPER REGION OF LH INBOARD ELEVON AND ANOTHER OBJECT FALLS

FROM AREA OF RH OMS POD. STILL ANOTHER OBJECT IS VISIBLE NEAR UNDERSIDE REGION OF LH INBOARD ELEVON (11-18 SECONDS MET). DEBRIS THIS EARLY IN FLIGHT IS USUALLY UMBILICAL ICE/FROST AND RCS PAPER COVERS.

E-57 96 FPS 35mm	Camera is located at camera site 6 on the NW pad perimeter. Remote tracking of lower one-third of launch vehicle from ignition to 1200 feet.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: WATER DELUGE SPRAYS FROM ET INTERTANK ACCESS STRUCTURE. ICE FALLS FROM FACILITY CRYOGENIC LINES AT ENGINE IGNITION. THE GH2 VENT LINE LATCHES PROPERLY. WATER FROM THE SRB STIFFENER RINGS VAPORIZES. A BIRD CROSSES THE FIELD OF VIEW, BUT IS FAR FROM THE VEHICLE. JUST BEFORE THE VEHICLE PASSES A CLOUD LAYER, 4 WHITE PARTICLES ARE VISIBLE NEAR THE RH WING (16 - 21 SECONDS MET). LITTLE CONDENSATE WAS PRESENT ON THE ET AFT DOME AND CHARRING OCCURS EARLY. RECTANGULAR-SHAPED, LIGHT-COLORED OBJECT FIRST APPEARS IN VICINITY OF RH OMS POD (30 SECONDS MET) AND IS VISIBLE AGAINST ORBITER WING AND FUSELAGE BEFORE DISAPPEARING INTO SRB PLUME - SUSPECT RH OMS POD CARRIER PANEL LOST DURING ASCENT.

E-58 96 FPS 35mm	Camera is located at camera site 6 on the NW pad perimeter. Remote tracking of center one-third of launch vehicle from ignition to 1200 feet.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: WATER VAPORIZES OFF ET AFT DOME. MANY SSME 'FLASHES' OCCUR DURING AND JUST AFTER ROLL MANEUVER. ONE OBJECT APPEARS PRIOR TO ROLL MANEUVER ORIGINATING FROM AFT END OF THE ORBITER. A BIRD CROSSES THE FIELD OF VIEW. A RECTANGULAR-SHAPED, LIGHT-COLORED OBJECT ORIGINATES NEAR THE RIGHT OMS POD (30 SECONDS MET) AND IS VISIBLE AGAINST THE WING AND ORBITER FUSELAGE FOR 7 FRAMES BEFORE DISAPPEARING INTO THE SRB PLUME - MAY BE THE FIBERGLASS CARRIER PANEL LOST FROM THE RH OMS POD DURING ASCENT.

E-59 96 FPS 35mm	Camera is located at camera site 6 on the NW pad perimeter. Remote tracking of upper one-third of launch vehicle from ignition to 1200 feet.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: WATER VAPORIZES OFF THE ET AFT DOME. MANY SSME "FLASHES" OCCUR DURING AND JUST AFTER ROLL MANEUVER. AN RCS PAPER COVER IS VISIBLE COMING FROM AFT END OF ORBITER PRIOR TO ROLL PROGRAM. A RECTANGULAR-SHAPED, LIGHT-COLORED OBJECT APPEARS IN THE REGION OF THE RIGHT OMS POD (30 SECONDS MET)AND IS VISIBLE AGAINST THE ORBITER WING AND FUSELAGE BEFORE DISAPPEARING INTO THE PLUME - MAY BE THE RH OMS POD CARRIER PANEL LOST DURING ASCENT.

E-60 96 FPS 35mm	Camera is located on north pad perimeter at camera site 1 and views the entire launch vehicle, FSS, and MLP zero level.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: WATER DELUGE SPRAYS FROM THE ET INTERTANK ACCESS STRUCTURE. ICE FALLS FROM THE FACILITY CRYOGENIC LINES AT ENGINE IGNITION. THE GH2 VENT LINE RETRACTS AND LATCHES PROPERLY. MORE THAN 20 BIRDS FLY EAST AWAY FROM THE VEHICLE SOON AFTER LIFTOFF. AS THE VEHICLE CLEARS THE TOWER, AN RCS PAPER COVER APPEARS FROM BEHIND SSME #1.

E-61 96 FPS 35mm	Camera is located at camera site 2 on the east pad perimeter and views the launch vehicle, FSS, and MLP.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: RUSTY DELUGE WATER IS SPRAYED ON MLP SOUTH SIDE BELOW ORBITER TAIL. ICE DROPS FROM FACILITY CRYOGENIC LINES AT ENGINE IGNITION. WATER DELUGE SPRAYS FROM ET INTERTANK ACCESS STRUCTURE. THE CIRCULAR FLOW OF EXHAUST GASES UNDER THE MLP AND UP THE NORTH SIDE CARRIES ICE/FROST PARTICLES FROM THE CRYOGENIC LINES TOWARD THE VEHICLE.

E-62 96 FPS 35mm	Camera is located on the SE pad perimeter at camera site 3 and views entire vehicle, FSS, and MLP.

Focus : OK
F. O. V.: OK
Exposure: OVEREXPOSED

Comments: RUSTY DELUGE WATER IS SPRAYED ON MLP SOUTH SIDE BELOW ORBITER TAIL. WATER FROM THE ET INTERTANK ACCESS STRUCTURE AND THE GO2 VENT ARM PASSES THE +Z SIDE OF THE ORBITER. ICE FALLS FROM THE FACILITY CRYOGENIC LINES AT ENGINE IGNITION. AS THE VEHICLE CLEARS THE TOWER, TWO BIRDS FLY OUTWARD IN A SOUTHERLY DIRECTION.

E-63 96 FPS 35mm	Camera is located on SW pad perimeter at camera site 4 and views entire launch vehicle, FSS, and MLP.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: BLUE SMOKE NEAR ORBITER SSME'S ORIGINATES FROM IGNITORS. RUSTY DELUGE WATER IS SPRAYED ON MLP SOUTH SIDE BELOW ORBITER TAIL. WATER FROM FSS PASSES +Z SIDE OF ORBITER. TWO BIRDS CROSS FIELD OF VIEW AS VEHICLE CLEARS TOWER. NO VEHICLE ANOMALIES WERE VISIBLE DURING EARLY ASCENT.

E-64 96 FPS 35mm	Camera is located on NW pad perimeter at camera site 6 and views entire launch vehicle, FSS, and MLP.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: WATER SPRAY FALLS FROM ET INTERTANK ACCESS STRUCTURE. ICE DROPS FROM FACILITY LH2 CRYOGENIC LINES AT ENGINE IGNITION. NO VEHICLE ANOMALIES.

E-65
80 FPS
16mm

Camera is located on east pad perimeter at camera site 2 and views ET LO2 feedline, ET intertank, and RH SRB as vehicle passes through the frame.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: GOOD VIEW OF VEHICLE 'TWANG'. ICE PARTICLES CONTINUE TO FALL FROM ET/ORB UMBILICALS. NO ET FEEDLINE ANOMALIES.

E-76
96 FPS
35mm

Camera is located on SE pad perimeter at camera site 3 and views SSME engines #1 and #3 and the RH OMS engine nozzle.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: BEFORE SSME PLUMES STABILIZE, RCS PAPER COVERS RUPTURE AND 10 TILE SHIMS FALL FROM BASE HEAT SHIELD BEHIND RH RCS STINGER. A WHITE RCS PAPER COVER FROM THE +Z SIDE OF THE STINGER, APPEARS BEHIND SSME #1 AND IS PROPELLED DOWNWARD. ICE FALLS FROM THE ORBITER LO2 T-0 UMBILICAL, WHICH RETRACTS NORMALLY. AS THE VEHICLE RISES, MANY ICE PARTICLES FALL PAST THE RH WING ABOVE THE LOX TSM. WATER TROUGH MATERIAL PASSES THE LH2 TSM AS THE VEHICLE CLEARS THE TOWER.

E-77
96 FPS
35mm

Camera is located on SW pad perimeter at camera site 4 and views SSME engines #1 and #2 and the LH OMS engine nozzle.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: THE FWD BUTCHER PAPER ON THE +Z SIDE OF THE -Y STINGER IS DISCOLORED. RCS PAPER COVERS RUPTURE AND RIP AWAY AT SSME IGNITION. ONE PARTICLE FALLS FROM THE LH2 TSM AS THE VEHICLE LEAVES THE FRAME. ONE PARTICLE MOVES BENEATH SSME #2. THE T-0 LH2 UMBILICAL SEPARATES NORMALLY. ONE OBJECT APPEARS NEAR THE TSM AFTER THE VEHICLE LEAVES THE FRAME.

E-78
200 FPS
16mm

Camera is located on SE pad perimeter at camera site 3 and views RH OMS Pod leading edge.

Focus : OK
F. O. V.: SLIGHTLY HIGH, SHOW MORE LEADING EDGE AT T-0
Exposure: SLIGHTLY UNDEREXPOSED

Comments: TPS WAS INTACT AND UNDAMAGED AS RH OMS POD PASSES THROUGH FIELD OF VIEW.

E-79
80 FPS
16mm

Camera is located on east pad perimeter at camera site 2 and views the ET nosecone, louver, and ogive.

Focus : SOFT
F. O. V.: OK
Exposure: OK

Comments: ET 'TWANG' IS APPROXIMATELY 33 INCHES. SOME FROST WAS PRESENT IN THE LOUVER. NO VEHICLE ANOMALIES WHILE PASSING THROUGH FRAME. ICE/FROST VISIBLE IN BELLOWS OF FEEDLINE AND RECIRCULATION LINE. THREE PIECES OF ICE FALL FROM UMBILICAL AREA.

E-201
30 FPS
70mm

UCS-10 IFLOT tracking of entire launch vehicle from ignition and early flight through LOV.

Focus : OK, BUT ATMOSPHERIC EFFECTS SOFTEN IMAGE
F. O. V.: OK
Exposure: SLIGHTLY UNDEREXPOSED

Comments: EXPOSURE DARKENS LATE IN FLIGHT AND ONLY SRB AND SSME PLUMES ARE VISIBLE.

E-202
30 FPS
70mm

UCS-15 IFLOT tracking of entire launch vehicle from ignition and early flight through LOV.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: FIVE OBJECTS, PROBABLY ICE PARTICLES, APPEAR AFT OF SSME'S DURING EARLY ASCENT. PLUME BLOCKS FIELD OF VIEW OF VEHICLE AFTER T+10 SECONDS.

E-203 UCS-6 IFLOT tracking of SRB and SRB exhaust plume
30 FPS from first acquisition to LOV. Exposed for flame.
70mm

Focus : FAIR
F. O. V.: GOOD
Exposure: FAIR FOR FLAME. UNDEREXPOSED FOR DETAIL.

Comments: LIGHT COLORED DEBRIS IS VISIBLE AT 5 AND 11 SECONDS MET. THIS DEBRIS IS PROBABLY UMBILICAL ICE OR RCS PAPER COVERS, BUT UNDEREXPOSED FILM PREVENTS DEFINITE IDENTIFICATION.

E-204 PAFB IGOR tracking of entire launch vehicle from
48 FPS acquisition to LOV. Tracks ET/ORB during and
35mm after SRB separation.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: JUST AFTER BOOSTER SEPARATION, AN OBJECT WITH A MAJOR DIMENSION OF ABOUT 10 FEET MOVES AWAY FROM THE BOOSTERS AT 14:32:43.5 (129.5 SECONDS MET) AND IS VISIBLE FOR 2.8 SECONDS. THE REDDISH/BROWN COLOR OF THE OBJECT IS NOT USUALLY ASSOCIATED WITH SRB SLAG AND MAY BE A PIECE OF EXTERNAL TANK INTERTANK FOAM FROM THE -Z SIDE OF THE VEHICLE.

E-205 Shiloh MIGOR tracking of entire launch vehicle
30 FPS from acquisition to LOV. Tracks ET/ORB during and
70mm after SRB separation.

Focus : SOFT DUE TO ATMOSPHERIC EFFECTS
F. O. V.: GOOD
Exposure: UNDEREXPOSED

Comments: RECIRCULATION EFFECT CHARS AFT DOME. NO DEBRIS IS VISIBLE AT SRB SEPARATION.

E-206 Melbourne Beach ROTI tracking of entire launch
40 FPS vehicle from acquisition to SRB separation. At
70mm separation, camera tracks south SRB to LOV.

Focus : OK, BUT ATMOSPHERE SOFTENS IMAGE
F. O. V.: OK
Exposure: OK

Comments: NO ANOMALIES DURING ASCENT.

E-207
40 FPS
70mm

UCS-10 MIGOR tracking of entire launch vehicle from acquisition to SRB separation. At separation, camera will track north SRB to LOV.

Focus : OK
F. O. V.: OK
Exposure: OK INITIALLY, UNDEREXPOSED LATER IN FLIGHT

Comments: SMALL PARTICLES APPEAR IN AND AROUND PLUME AFTER PAD CLEAR AND ROLL MANEUVER. THE AFT DOME OF ET APPEARS CHARRED DURING ASCENT. NO LOSS OF TPS NOTED ON AFT DOME. SEVERAL OBJECTS FALL FROM SRB NOZZLES AFTER BOOSTER SEPARATION AND ARE PROBABLY SLAG OR PIECES OF INHIBITOR.

E-209
30 FPS
70mm

UCS-13 IFLOT intermediate tracking of entire launch vehicle from acquisition to LOV.

Comments: FILM BROKE - ITEM DID NOT RUN

E-210
30 FPS
70mm

UCS-26 IFLOT intermediate tracking of entire launch vehicle from liftoff to LOV.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: END OF FILM OBSCURED BY SMOKE. UPPER RIGHT PLUME SHOWS BRIGHT STREAK PRIOR TO SRB SEPARATION, BUT DISTANT VIEW DOES NOT PROVIDE SUFFICIENT DETAIL. NO DEBRIS VISIBLE AT SRB SEPARATION.

E-214
32 FPS
16mm

UCS-15 IFLOT close-in tracking of entire launch vehicle during ignition, liftoff, and early portion of flight through LOV.

Focus : OK
F. O. V.: OK
Exposure: UNDEREXPOSED

Comments: INITIAL LIFTOFF OBSCURED BY SSME PLUME. AT LEAST THREE FLASHES ARE VISIBLE IN THE SSME PLUME IN EARLY STAGES OF ASCENT. DEBRIS IS VISIBLE AT 7, 13, AND 24 SECONDS MET, BUT UNDEREXPOSURE OF FILM PREVENTS IDENTIFICATION OF THESE OBJECTS.

E-215
32 FPS
16mm

UCS-10 IFLOT close-in tracking of entire launch vehicle during ignition, liftoff, and early portion of flight through LOV.

Focus : SOFT
F. O. V.: OK
Exposure: UNDEREXPOSED

Comments: VEHICLE IS BACKLIT BY SUN'S POSITION AND UNDEREXPOSURE OF FILM PREVENTS FINE DETAIL FROM BEING DISCERNIBLE. ONE OBJECT IS VISIBLE AT 29 SECONDS MET - MAY BE RH OMS POD CARRIER PANEL LOST DURING ASCENT.

E-216
48 FPS
70mm

UCS-6 IFLOT tracking of base of SRB exhaust plume from first acquisition to LOV. Exposed for flame.

Focus : OK
F. O. V.: OK
Exposure: UNDEREXPOSED

Comments: UNDEREXPOSURE PREVENTS FINE DETAIL FROM BEING DISCERNIBLE. BIRD CROSSES FIELD OF VIEW CLOSE TO CAMERA BEFORE ROLL PROGRAM HAS STARTED. DEBRIS VISIBLE AT 5 AND 9 SECONDS MET IS PROBABLY UMBILICAL ICE OR RCS PAPER COVERS. AFT DOME IS CHARRED EARLY IN FLIGHT. NO DAMAGE TO ORBITER WING TILES IS VISIBLE. OBJECT APPEARING AT 30 SECONDS MET MAY BE RH OMS POD CARRIER PANEL LOST DURING ASCENT. NUMEROUS LIGHT OBJECTS IN LINE WITH THE VEHICLE PLUME MAY BE DEBRIS, BUT ARE MORE LIKELY FILM DEFECTS (OCCURS JUST AFTER SRB SEPARATION).

E-217
30 FPS
70mm

Beach Road IFLOT tracking of Orbiter from liftoff through early flight.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: ICE/FROST GENERATED BY COOLED SSME NOZZLES CONTINUES TO FALL AFTER TOWER CLEAR. THREE PIECES OF ICE APPEAR UNDER BODY FLAP FOR SEVERAL SECONDS PRIOR TO ROLL MANEUVER. DEBRIS VISIBLE AT 9, 17, AND 19 THROUGH 32 SECONDS MET IS PROBABLY MORE UMBILICAL ICE AND RCS PAPER COVERS.

VIDEO ITEMS

OTV 101 Views aft end of Orbiter from the FSS 255 foot level.
B/W M-II

Comments: CAMERA APPEARS TO BE OVERDRIVEN. NO VEHICLE ANOMALIES.

OTV 103 Views GUCP and GH2 vent line.
B/W M-II

Comments: GUCP DISCONNECT AND RETRACTION IS NOMINAL. A FEW SMALL ICE/FROST PARTICLES ARE RELEASED AT DISCONNECT.

OTV-109 Views ET/Orbiter LH2 umbilical area from the 95 foot level of the FSS.
B/W M-II

Comments: ICE ACCUMULATION ON ET/ORB LH2 UMBILICAL BAGGIE IS SHAKEN LOOSE BY SSME IGNITION.

OTV 111 Views GUCP and GH2 vent line with new Insight IR camera.
B/W IR

Comments: CAMERA NOT POINTED AT VEHICLE FOR LAUNCH.

OTV 119 Views LH2 umbilical with new Insight IR camera.
B/W IR

Comments: CAMERA NOT POINTED AT VEHICLE FOR LAUNCH.

OTV 130 Views SSMEs and Orbiter aft end from SE pad apron with new Insight IR camera.
B/W IR

Comments: CAMERA POINTED AT SSME FLAME TRENCH DURING LIFTOFF. NO INFRARED SIGNATURE OF HYDROGEN FIRE.

OTV 134 Views MLP side 1 (south) LH2 skid.
B/W

Comments: CAMERA POINTED SOUTHEAST DURING LAUNCH.

OTV 135 Views base of the FSS.
B/W

Comments: CAMERA POINTED SOUTH DURING LAUNCH.

OTV 141 Views and tracks vehicle from camera site 2.
B/W

Comments: WATER AND CONDENSATE FROM ET AFT DOME AND SRB STIFFENER RINGS VAPORIZES. GOOD VIEW OF ROLL MANEUVER.

OTV 143 Views east side of launch vehicle and pad from camera site 2.
B/W

Comments: GOOD VIEW OF VEHICLE 'TWANG'.

OTV 148 Launch and tracking view from camera site 6.
B/W
Comments: VEHICLE IS BACKLIT BY SUN'S POSITION. GOOD VIEW OF ROLL MANEUVER.

OTV 149 Views Orbiter LO2 T-0 umbilical from MLP deck.
B/W M-II

Comments: ICE FALLS FROM UMBILICAL AT SSME IGNITION. ORBITER LO2 T-0 UMBILICAL DISCONNECT AND SEPARATION IS NOMINAL. PIECES OF ICE CONTINUE TO FALL FROM BEHIND BODY FLAP.

OTV 150 Views Orbiter LH2 T-0 umbilical from SW MLP deck.
B/W M-II

Comments: ICE FALLS FROM UMBILICAL DURING SSME IGNITION. ORBITER LH2 T-0 UMBILICAL DISCONNECT AND RETRACTION IS NORMAL. TWO TILES ON RCS STINGER HAVE BEEN CHIPPED BY SSME STARTUP ACOUSTICS.

OTV 151 Views Orbiter main engines.
B/W M-II

Comments: RCS PAPER COVERS RUPTURE AND ICE/FROST PARTICLES FALL FROM ORBITER LO2 T-0 UMBILICAL AT SSME IGNITION. SSME STARTUP APPEARS NORMAL.

OTV 154 Views ET/Orbiter LO2 umbilical and Orbiter RH wing
B/W M-II

Comments: CONSIDERABLE CAMERA SHAKE DURING SSME IGNITION. SHOWER OF ICE/FROST PARTICLES ORIGINATES FROM ET/ORB UMBILICALS.

OTV 155 Views RH SRB and Orbiter body flap.
B/W M-II

Comments: LARGE PIECES OF ICE ARE SHAKEN LOOSE FROM ET/ORB LH2 UMBILICAL BY SSME IGNITION AND FALL EASTWARD TOWARD RH SRB HOLDDOWN POSTS.

OTV 156 Views LH SRB and Orbiter body flap.
B/W M-II

Comments: SSME IGNITION SHAKES ICE LOOSE FROM ET/ORB LH2 UMBILICAL. NO DAMAGE TO TILES ON BODY FLAP OR ELEVONS IS VISIBLE.

OTV 160 Views ET nosecone and NE louver from water tower.
Color M-II

Comments: LIGHT FROST COATS OUTER RIM OF LOUVER, BUT NO ICE IS VISIBLE. CAMERA SHAKES CONSIDERABLY DURING SSME IGNITION. NO TPS ANOMALIES ON OGIVE. NO TILE DAMAGE ON BODY FLAP.

ORIGINAL PAGE IS
OF POOR QUALITY

OTV 161 Views ET nosecone and SW louver from the FSS.
Color M-II

Comments: WATER DELUGE FROM FSS OBSCURES VIEW. FROST HAS ACCUMULATED OVER ABLATOR-COVERED FASTENERS. NOTHING FALLS FROM ET NOSE CONE FAIRING. NO OGIVE TPS ANOMALIES.

OTV 163 Views ET/Orbiter umbilical and Orbiter T-0 umbilical from the FSS.
Color M-II

Comments: WATER DELUGE FROM FSS OBSCURES VIEW. LH WING TILES ARE WET.

OTV 170 Views overall vehicle from SE direction.
Color M-II

Comments: RUSTY DELUGE WATER IS SPRAYED ON SOUTH SIDE OF MLP. FREE HYDROGEN IS BURNING NEAR SSME #1. SSME IGNITION APPEARS NORMAL. RCS PAPER COVERS RUPTURE AND LO2 T-0 UMBILICAL SHEDS ICE AT ENGINE STARTUP. VERY LITTLE OMS NOZZLE MOVEMENT. LO2 T-0 UMBILICAL DISCONNECT IS NOMINAL. SOME FACILITY DEBRIS FLIES THROUGH FIELD OF VIEW AFTER VEHICLE HAS CLEARED TOWER.

OTV 171 Views overall vehicle from SW direction.
Color M-II

Comments: FREE HYDROGEN IS IGNITED BY SOUTHWEST IGNITOR AND QUICKLY DISSIPATES. RCS PAPER COVERS RUPTURE AND ICE/FROST PARTICLES FROM LO2 T-0 UMBILICAL FALL AT SSME IGNITION. ENGINE START APPEARS NORMAL. VERY LITTLE OMS NOZZLE MOVEMENT. SMALL PIECE OF DEBRIS FROM SSME FLAME TRENCH FOLLOWS VEHICLE ASCENT BRIEFLY.

OTV 172 Views SSMEs with new Insight IR camera from SW corner of MLP deck.
B/W IR

Comments: CAMERA POINTED DOWN INTO SSME FLAME TRENCH DURING LAUNCH. SOME HEAT PATTERNS ARE VISIBLE IN THE SSME PLUME, BUT NO TEMPERATURE SCALE IS IN THE FIELD OF VIEW.

TV-1 Views launch from SLF mid-field position.
Color M-II

Comments: VEHICLE FLIES STRAIGHT UP (DIRECT INSERTION) AND HIGH INCLINATION TRAJECTORY. ALTHOUGH AFFECTED BY WINDS ALOFT, NO PLUME ANOMALIES ARE VISIBLE. NO DETAIL OF SRB SEPARATION.

TV2 Views launch from SLF convoy position.
Color M-II

Comments: NO PLUME ANOMALIES. VERY LITTLE DETAIL OF SRB SEP.

TV-3 Views entire launch vehicle from UCS 9.
Color M-II

Comments: VEHICLE IS BACKLIT BY SUN'S POSITION. TOO MUCH CAMERA SHAKE. CLOUDS PARTIALLY OBSCURE VIEW. NOT MUCH DETAIL ON SRB SEP.

TV-4 Views entire vehicle from Beach Road IFLOT Site.
Color M-II

Comments: RUSTY DELUGE WATER IS SPRAYED ON SOUTH SIDE OF MLP. ICE IS SHAKEN LOOSE FROM CROSS COUNTRY CRYOGENIC LINES BY SSME IGNITION. HYDROGEN BURNS UNDER MLP UNTIL SSME PLUMES HAVE STABILIZED. WATER FROM SRB STIFFENER RINGS VAPORIZES. FLASH OCCURS IN SSME PLUME 38 AND 41 SECONDS INTO FLIGHT.

TV-5 Views launch from VAB roof.
Color M-II

Comments: AFT DOME CHARRING OCCURS EARLY DUE TO LACK OF CONDENSATE. NO DETAIL ON SRB SEPARATION.

TV-6 Color M-II	Views entire launch vehicle from DLTR-3 site directly south of Pad B.

Comments: RUSTY DELUGE WATER IS SPRAYED ON SOUTH SIDE OF MLP. GOOD VIEW OF ROLL MANEUVER.

TV-7 Color M-II	Views entire launch vehicle from camera site 2 east of pad.

Comments: RUSTY DELUGE WATER IS VISIBLE ON SOUTH SIDE OF MLP. BURNING HYDROGEN IS VISIBLE UNDER MLP IN SSME FLAME TRENCH. VEHICLE 'WALKS' TO THE NORTH BEFORE TOWER CLEAR. WATER/CONDENSATE FROM ET AFT DOME AND SRB STIFFENER RINGS VAPORIZES.

TV-13 Color M-II	Views launch from Patrick ROTI tracker.

Comments: ET AFT DOME CHARS EARLY DUE TO LACK OF CONDENSATE. NO TILE ANOMALIES VISIBLE ON LH WING AND ELEVON. GOOD DETAIL ON ET FLIGHT DOOR, RSS ANTENNA, AFT HARDPOINT. SHORTLY AFTER SRB SEP, LIGHT COLORED OBJECT NEAR RH SRB FORWARD SKIRT AREA FOLLOWS DIFFERENT TRAJECTORY THAN THAT OF THE SRB'S. AFT BOOSTERS OF BOTH SRB'S HAVE BEEN DARKENED SLIGHTLY.

TV-16 Color M-II	View from helicopter orbiting west of pad and VAB.

Comments: STRAIGHT UP (DIRECT INSERTION) TRAJECTORY ISEVIDENT. PLUME IS AFFECTED BY WINDS ALOFT.

TV-18 Color M-II	Views launch and tracks from Malabar ITEC.

Comments: CAMERA PROBLEMS AND ATMOSPHERIC EFFECTS OBSCURE DETAIL

ET-204 U-Matic	Patrick IGOR video. Tracks launch vehicle from acquisition to LOV and continues to track ORB/ET after SRB separation.

Comments: A MOMENTARY FLASH OCCURS ON THE LH SIDE OF THE ORBITER IN THE VICINITY OF THE CREW HATCH AT 14:30:49.9 GMT. THIS FLASH WAS CAUSED BY SUNLIGHT REFLECTING OFF THE WINDOW IN THE CREW HATCH AS THE VEHICLE CHANGED ORIENTATION DURING THE ROLL MANEUVER. NO OVERALL VEHICLE ANOMALIES DURING ASCENT WERE OBSERVED.

ET-205 U-Matic	Shiloh MIGOR video. Tracks launch vehicle from acquisition to LOV and continues to track ORB/ET after SRB separation.

Comments: AFT DOME CHARRING FROM RECIRCULATION EFFECTS BEGINS AT 337:14:32:07.6 (47 SECONDS IN FLIGHT). EXPOSURE IS DARK DURING SRB SEPARATION AND NOT MUCH DETAIL IS VISIBLE.

ET-206 U-Matic	Melbourne Beach video. Tracks launch vehicle from acquisition to SRB separation, then continues to track south SRB to LOV.

Comments: ATMOSPHERIC EFFECTS AND CAMERA SHAKE OBSCURE FINE DETAIL. SRB SEPARATION IS NORMAL AND AFT BOOSTERS OF BOTH SRB'S HAVE BEEN DARKENED SLIGHTLY. AT 337:14:32:43.7, A LIGHT COLORED PARTICLE IS FIRST VISIBLE NEAR THE RH SRB AFT SKIRT MOVING TO THE LEFT SIDE OF THE FRAME. AFT DOME OF THE ET HAS BEEN CHARRED.

ET-207 U-Matic	UCS-10 MIGOR video. Tracks launch vehicle from acquisition to SRB separation, then continues to track north SRB to LOV.

Comments: WATER DELUGE SPRAYS FROM FSS 275 FOOT LEVEL. WATER AND CONDENSATE FROM THE ET AFT DOME AND SRB STIFFENER RINGS VAPORIZES. GOOD VIEW OF ROLL MANEUVER. VIEW IS OBSCURED FROM TIME TO TIME BY CLOUDS.

ET-208 Cocoa Beach ROTI video. Tracks launch vehicle
U-Matic from acquisition to LOV.

Comments: CHARRING OCCURS EARLY ON ET AFT DOME DUE TO LACK OF CONDENSATE. TILES ON LH WING APPEAR UNDAMAGED. SRB SEPARATION IS NOMINAL. JUST AFTER SEPARATION, A LIGHT COLORED OBJECT APPEARS NEAR THE RH SRB FORWARD SKIRT AT 337:14:32:43.8. SRB PLUME OBSCURES DETAIL, BUT OBJECT APPEARS TO PASS IN FRONT OF BOOSTER AND IS MOMENTARILY VISIBLE IN AREA BETWEEN SRB'S. OBJECT MAY HAVE ORIGINATED FROM LH SRB AFT SKIRT AREA OR EXTERNAL TANK. OBJECT CONTINUES TO MOVE TOWARD UPPER LEFT CORNER OF FRAME AND IS INDEPENDENT OF SRB PLUME. SLAG FROM THE LH SRB IS VISIBLE AT 337:14:32:52.4.

8.0 SRB POST FLIGHT/RETRIEVAL DEBRIS ASSESSMENT

Both Solid Rocket Boosters and frustums were inspected for debris damage and sources at CCAFS Hangar AF on 5 December 1988 from 0830 to 1230 hours. The SRB nosecaps were not recovered and were therefore not included in the assessment.

8.1 RH SOLID ROCKET BOOSTER DEBRIS INSPECTION

The RH frustum exhibited 4 TPS debonds, which did not extend to substrate, and no areas of missing TPS (Fig 11). All BSM covers were intact and locked in the open position.

The RH FWD skirt TPS exhibited no debonds and 2 divots. A 2-inch gouge was present near the skirt access door. Scorching of the Hypalon paint had occurred forward of the thrust fitting and on the aft side of the RSS banjo fitting. Both RSS antenna phenolic plates were attached (Fig 12). Separation appeared nominal at the forward attach fitting.

The TPS and Hypalon topcoat on the frustums and forward skirts continue to have adhesion problems. Although the black paint of the visibility stripe was blistered and peeled over much of the surface area, the white Hypalon paint beneath the black paint did not exhibit the blistering phenomenon. However, many other areas of the white Hypalon paint had blistered. Some of the blisters had vented and were missing pieces (cratering). Examination of the cross sectional area of the the blisters revealed some were the thickness of the paint while others were a combination of paint and MSA 1/32 to 1/16-inch thick. The inclusion of the MSA indicates the formation of divots within the TPS.

All factory and field joint closeouts were undamaged except for the center field joint. A 3.5-inch diameter divot to substrate at the Kevlar strap connecting clip, located at 185 degrees, showed debonding around the circumference. This was caused by trapped air at the cork trim out for the clip. This fit problem did not occur on any of the other joints or on STS-26R. System tunnel covers were in place and closeouts were intact with only minor gouges. DFI cork runs had general trailing edge damage with some areas showing fore-to-aft scrape marks, which could be signs of debris impacts.

Stiffener rings were not damaged. The ETA ring was in good condition except for a two foot section of missing instafoam caused by water impact. Separation of the aft ET/SRB struts appeared nominal though one upper strut electrical connector shell was damaged.

All four of the aft skirt debris containers with attaching bolts were intact, but the lockwire had melted or broken on post #1 and #2. The lockwire was intact on posts #3 and #4. The

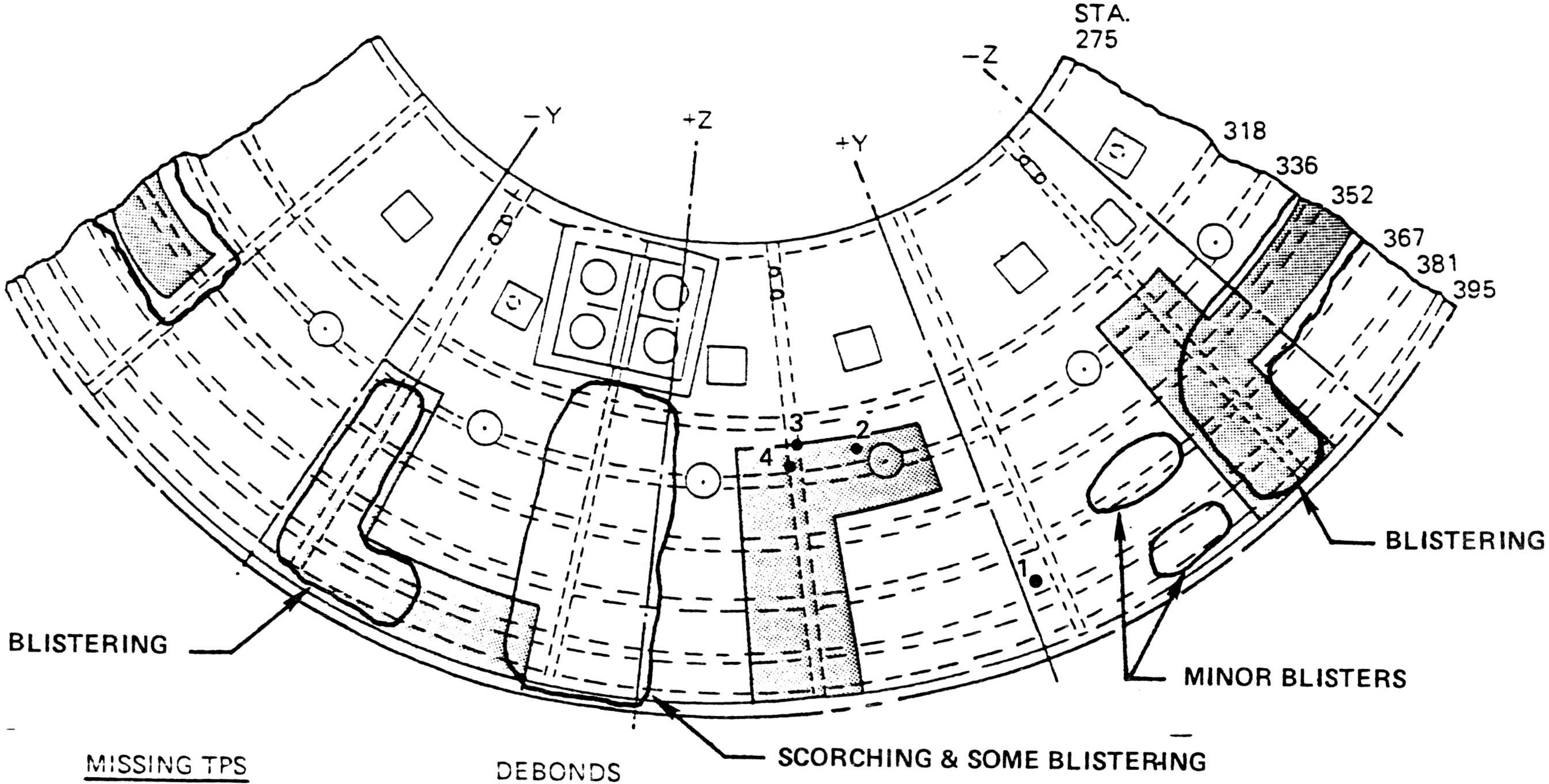


FIGURE 11. RIGHT SRB FRUSTUM

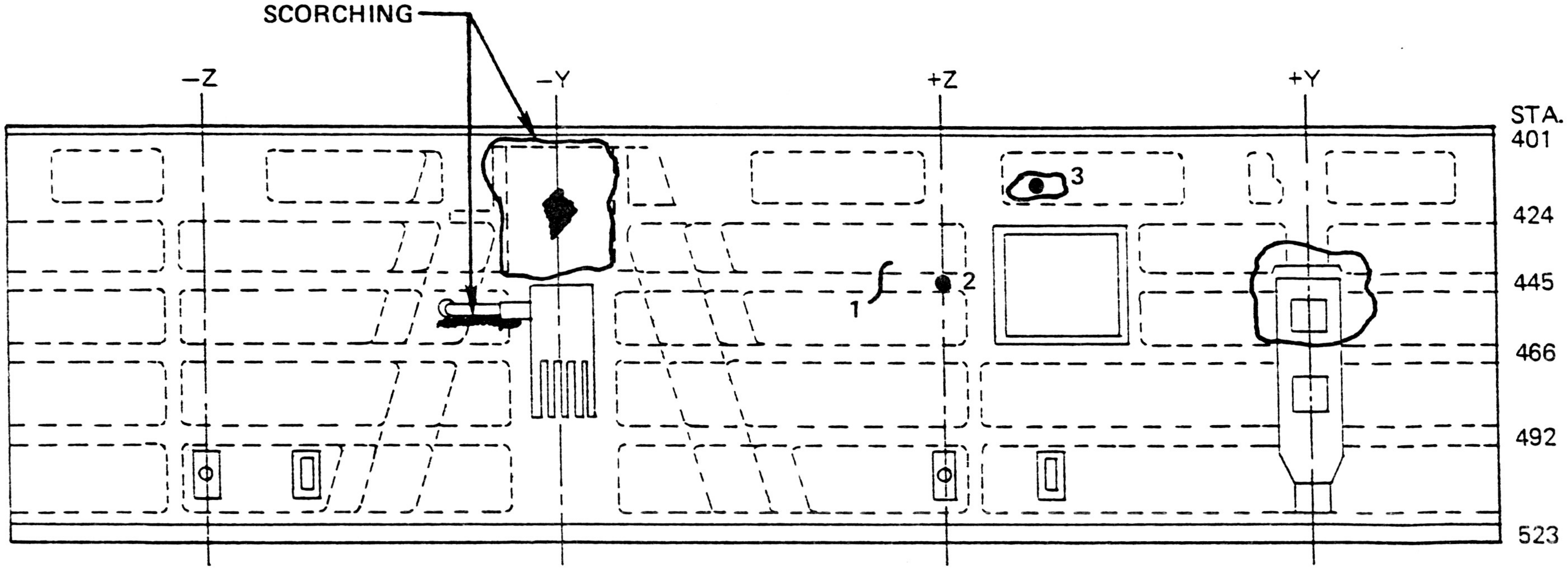
MISSING TPS

NONE

DEBONDS

NONE TO SUBSTRATE
1. ½" LONG
2. 1" DIA
3. ½" DIA
4. ¾" DIA

FIGURE 12. **RIGHT SRB FWD SKIRT**



TPS MISSING

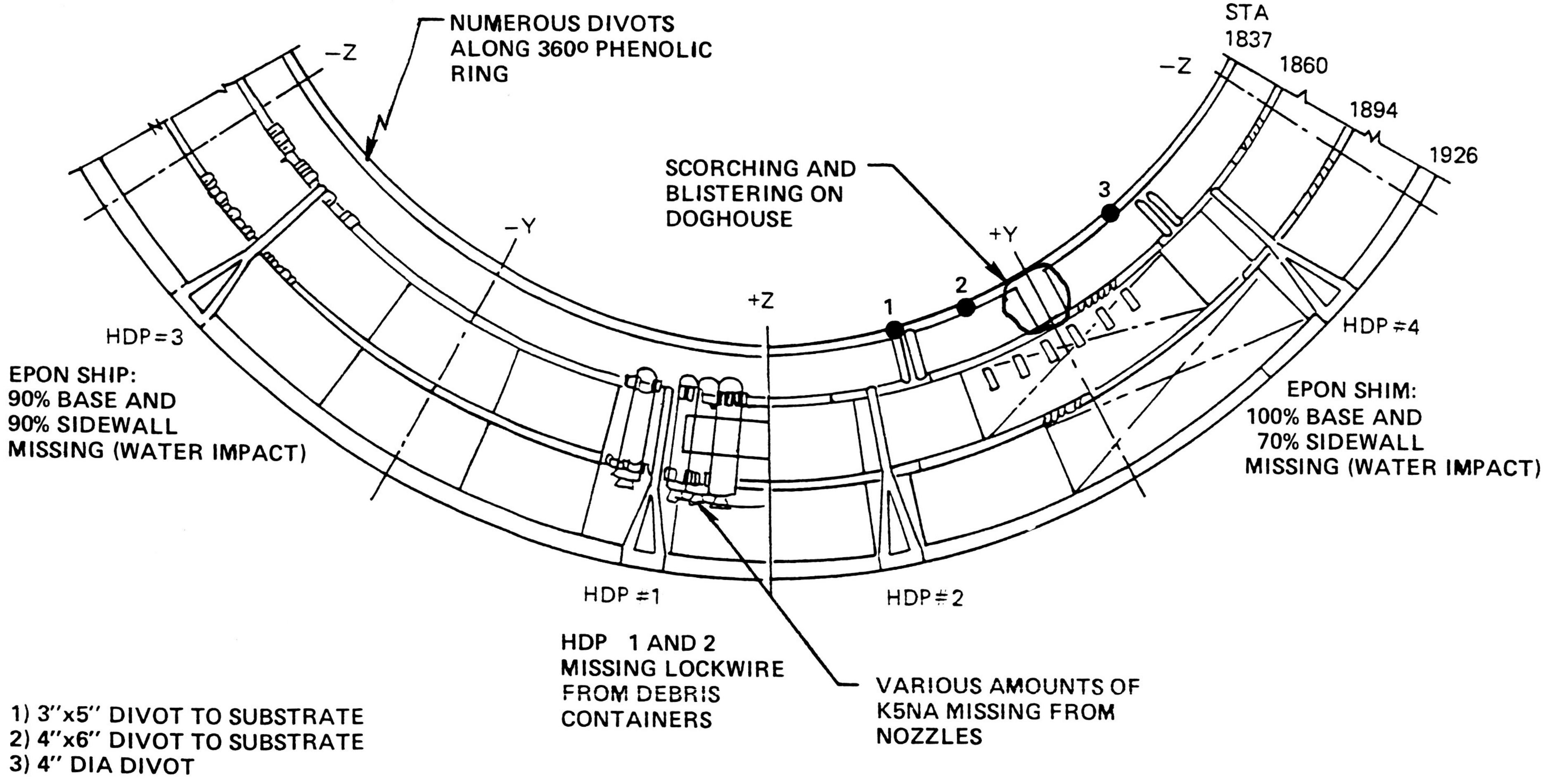
1) 2″ GOUGE
2) 1″ DIVOT
3) 3″ DIA DIVOT TO SUBSTRATE

DEBONDS

NONE

NOTE: BLISTERING OF HYPALON PAINT OCCURRED IN OUTLINED AREAS.

FIGURE 13. **RIGHT SRB AFT SKIRT EXTERIOR TPS**



#3 and #4 debris plungers exhibited a 1/4-inch gap held open by small pieces of Epon shim material. This apparently occurred at water impact. Film review indicated that the plungers seated properly at launch. Ninety percent of the base and 90% of the sidewall on Epon shim #3 was lost at water impact. Epon shim #4 was missing 100% of the base and 70% of the sidewall, but showed clean substrate. K5NA was missing from all aft BSM nozzle rings. The TPS on the aft skirt was generally in good condition with the exception of delamination and divots on the phenolic kick ring (Fig 13).

8.2 LH SOLID ROCKET BOOSTER DEBRIS INSPECTION

The LH frustum exhibited no TPS debonds or divots (Fig 14). All BSM covers were still attached, but the two left covers were bent at the hinge. This damage reportedly occurred during retrieval operations.

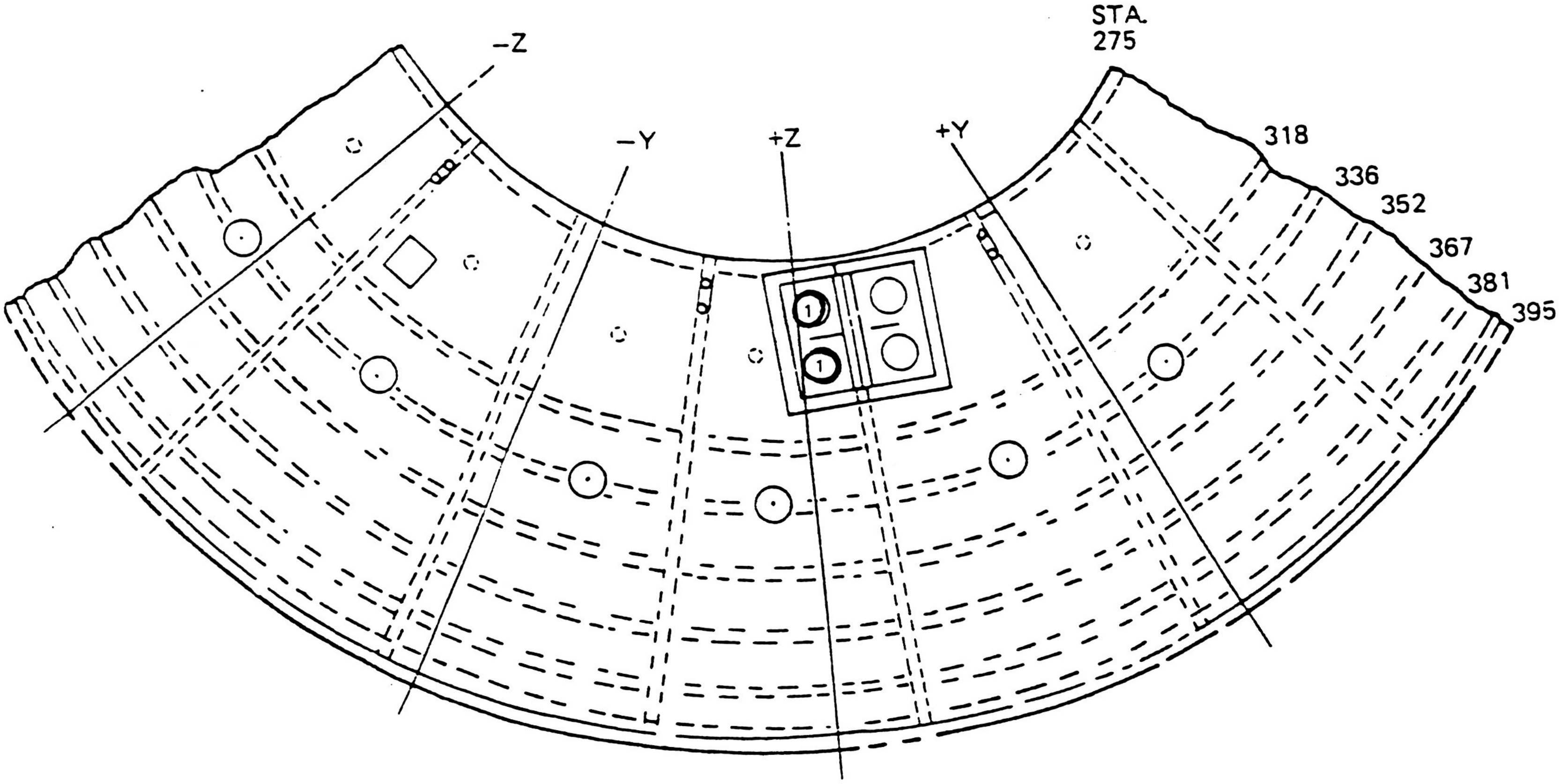
Four TPS divots, but no debonds, were visible on the LH FWD skirt. Some scorching of the Hypalon paint had occurred forward of the ET attach point and aft of the banjo fitting. Phenolic plates were still attached to the RSS antenna covers (Fig 15). Structurally, separation of the ET/SRB flight bolt appeared nominal.

All factory and field joint closeouts were in good condition. System tunnel covers were in place and K5NA closeouts were intact. DFI cork runs showed general trailing edge damage in the form of small, localized cohesive failures during ascent and at water impact. Three 1-inch diameter debonds (no missing material) occurred on the outboard face of the pressure transducer cork ramps at 170 and 200 degrees on the LH FWD segment.

Stiffener rings, instafoam, and the IEA structure sustained only minor water impact damage. Aft ET/SRB struts had separated normally though one upper strut electrical connector shell was damaged.

All four of the aft skirt debris containers with attaching bolts were intact, but the lockwire had melted or broken on post #5 and #6. The lockwire was intact on posts #7 and #8. The #5 debris plunger did not seat properly and left a 1/8-inch gap. Twenty percent of the base and none of the sidewall on Epon shim #7 was lost at water impact. Epon shim #8 lost 20% of the base and 30% of the sidewall during ascent followed by another 60% of the base at water impact. The aft skirt TPS was generally in good condition with the exception of missing K5NA from all of the aft BSM nozzle rings and delamination on the phenolic kick ring (Fig 16).

FIGURE 14. LEFT SRB FRUSTUM



MISSING TPS

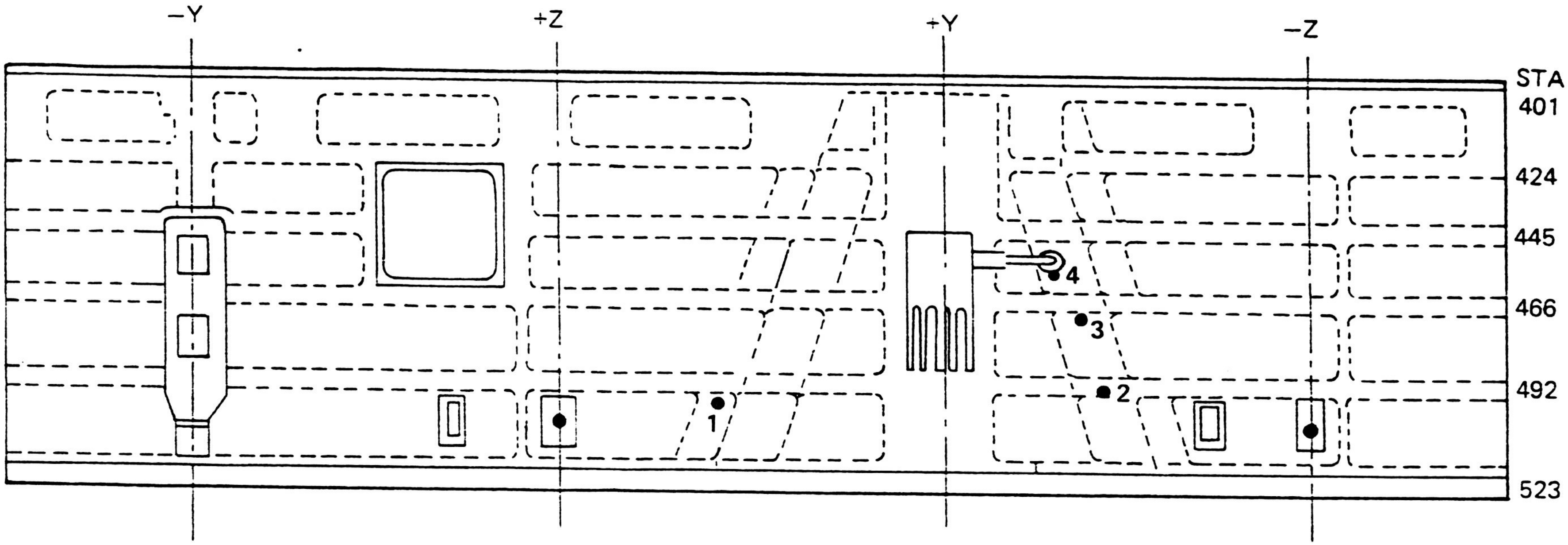
NONE

DEBONDS

NONE

NOTE: 1) Left Top and Bottom BSM covers bent at hinge.

FIGURE 15. **LEFT SRB FWD SKIRT**



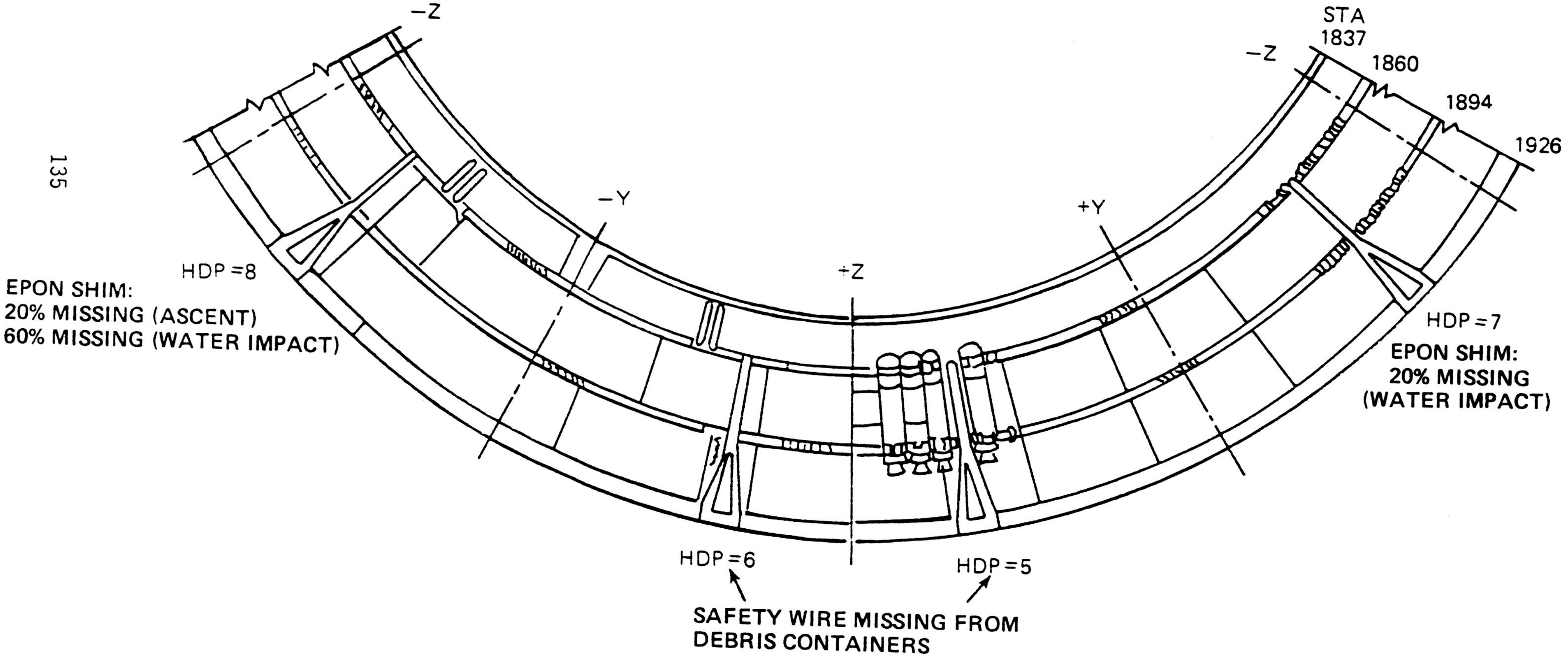
TPS MISSING

1. 1½" DIA TPS
2. ½" x ¼"
3. 2" x 1"
4. 2" x ½"

DEBONDS

NONE

FIGURE 16. LEFT SRB AFT SKIRT EXTERIOR TPS



8.3 RECOVERED SRB DISASSEMBLY FINDINGS

Joint vent valve failure again caused water intrusion in five of the six field joints. The valves had been functionally checked and sealed against fluid inflow while in the VAB.

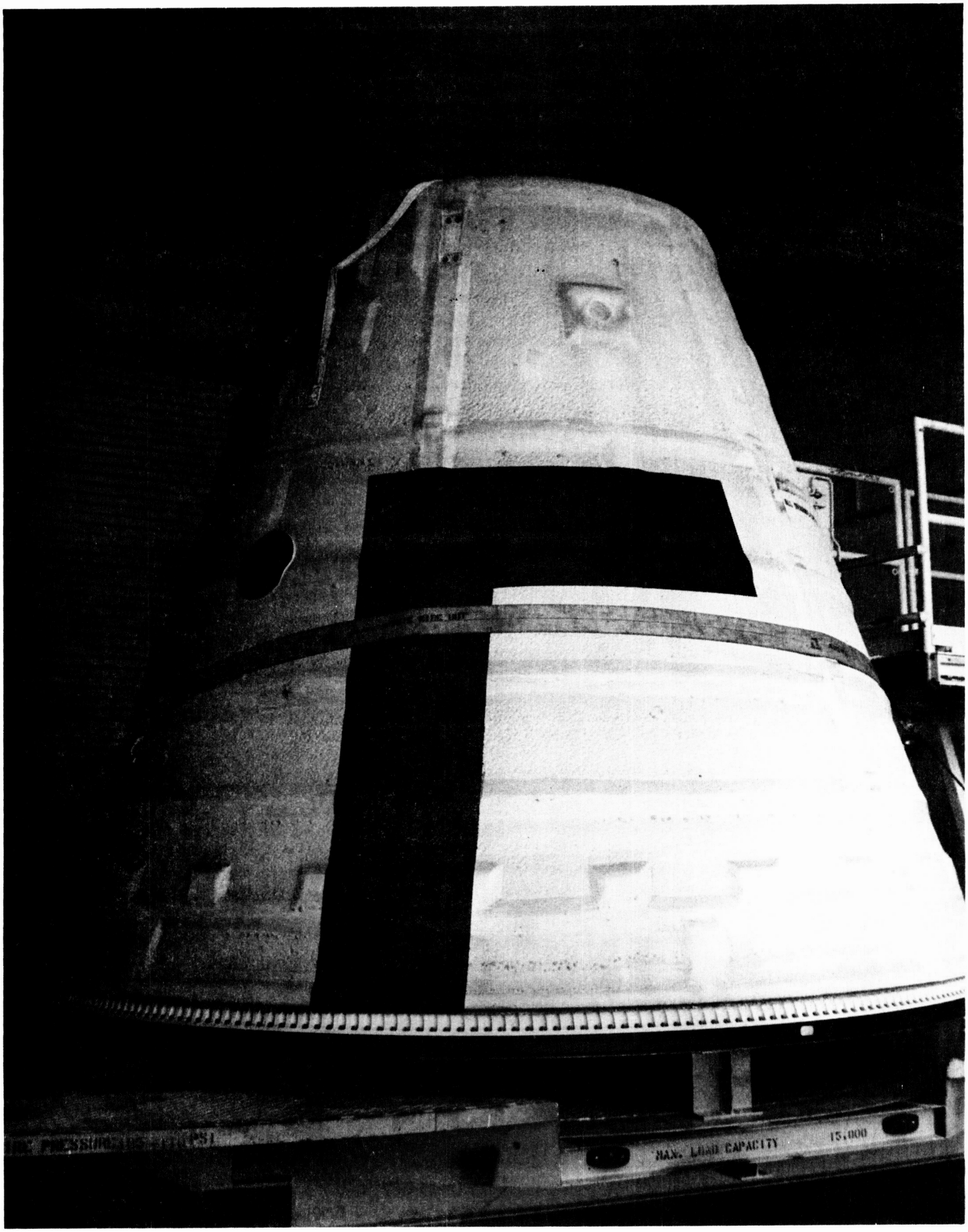
The SRM field joints were demated and initial inspections show that the J-joint performance in all joints appears nominal with no O-ring anomalies. The joints did exhibit the same cold welding (fretting) that had occurred on STS-26R. Tang pitting from the cold welding was worse on this flight.

Visual evidence shows complete backfilling of both nozzle exit cone field joints had not been achieved. The process is very operator sensitive and cannot be inspected.

Three locations were identified where K5NA had not been applied on system tunnel cover joints during closeout work. The installation procedures are correct and will be assessed for any needed engineering refinement of the OMI.

The igniter heater on each SRM was scorched because full contact was not maintained with the flange. This first flight installation was performed by MTI plant personnel at KSC and the hot spots were located where the heater band crossed DFI wiring, which had been previously installed at the plant and delivered to KSC.

The igniters performed properly although both exhibited blowholes in the outer putty installations. The LH igniter inner putty installation also had a blowhole. However, all blowholes are considered nominal conditions by MTI. A raised metal imprint was found on the LH igniter FWD dome boss adjacent to the 297 bolt hole. The imprint appears to have occurred during assembly and did not degrade the igniter joint seal.



RH SRB FRUSTUM EXHIBITING MINIMAL DAMAGE

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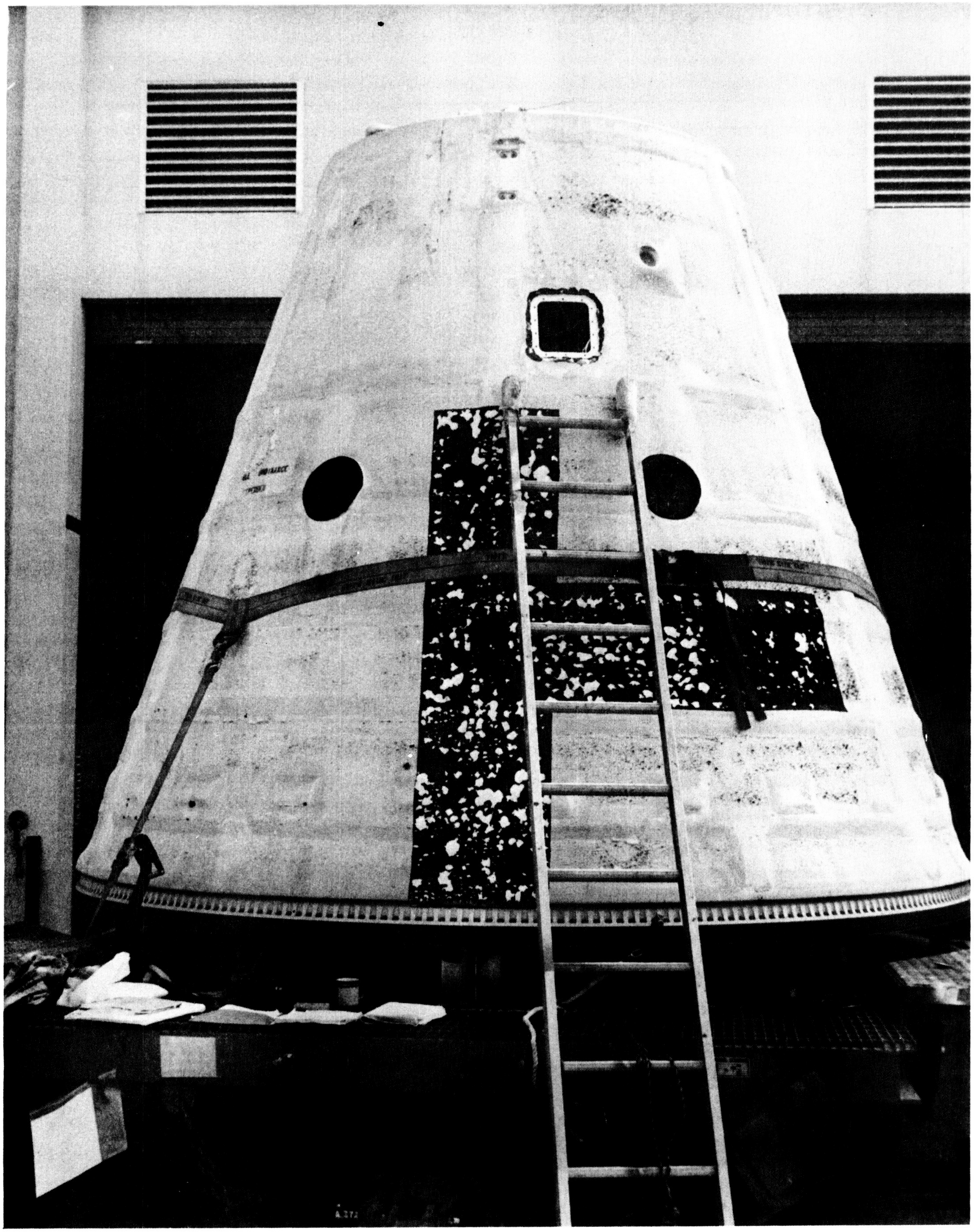

HYPALON PAINT BLISTERING ON LH SRB FRUSTUM

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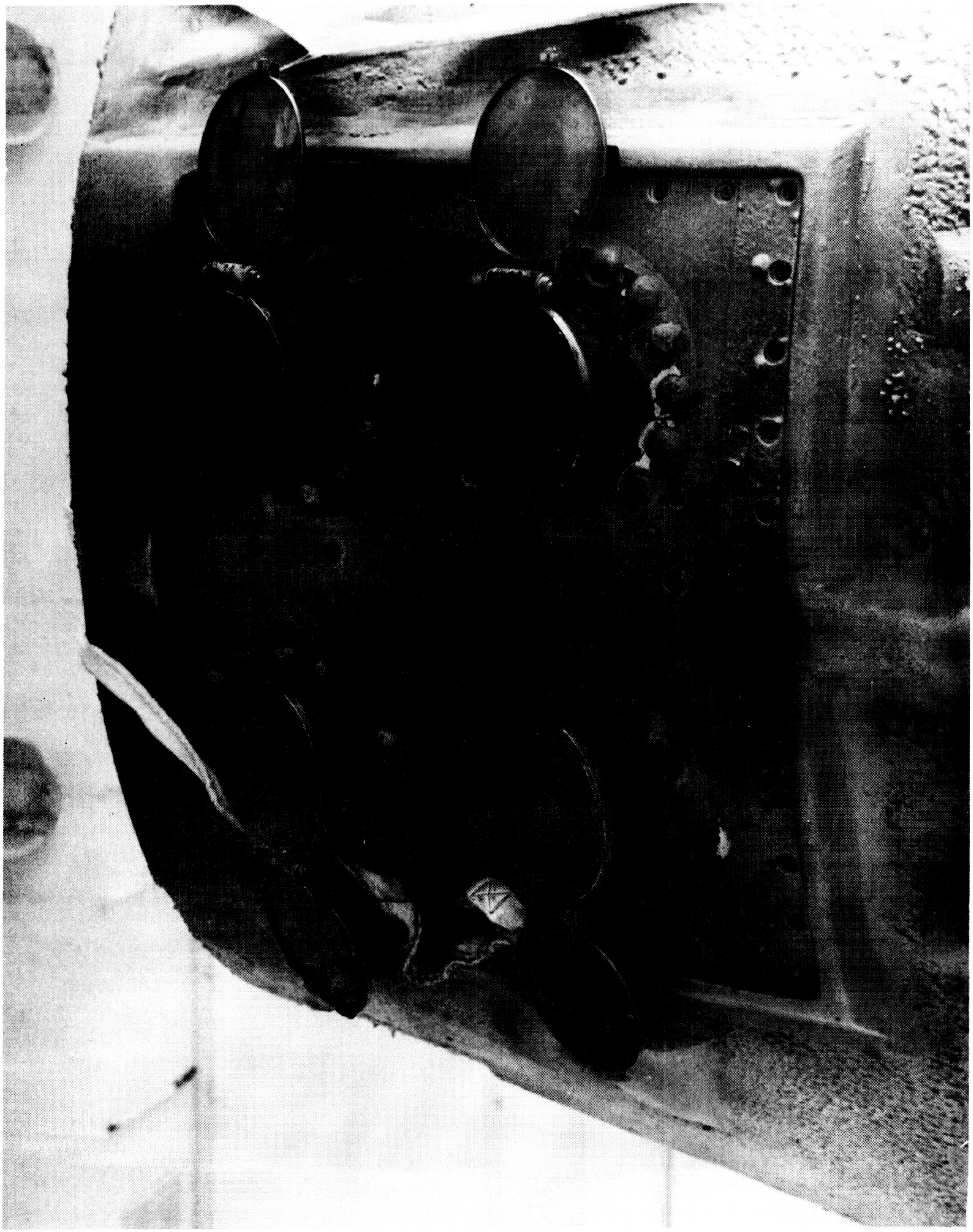

BSM COVERS ARE INTACT ON RH SRB FRUSTUM

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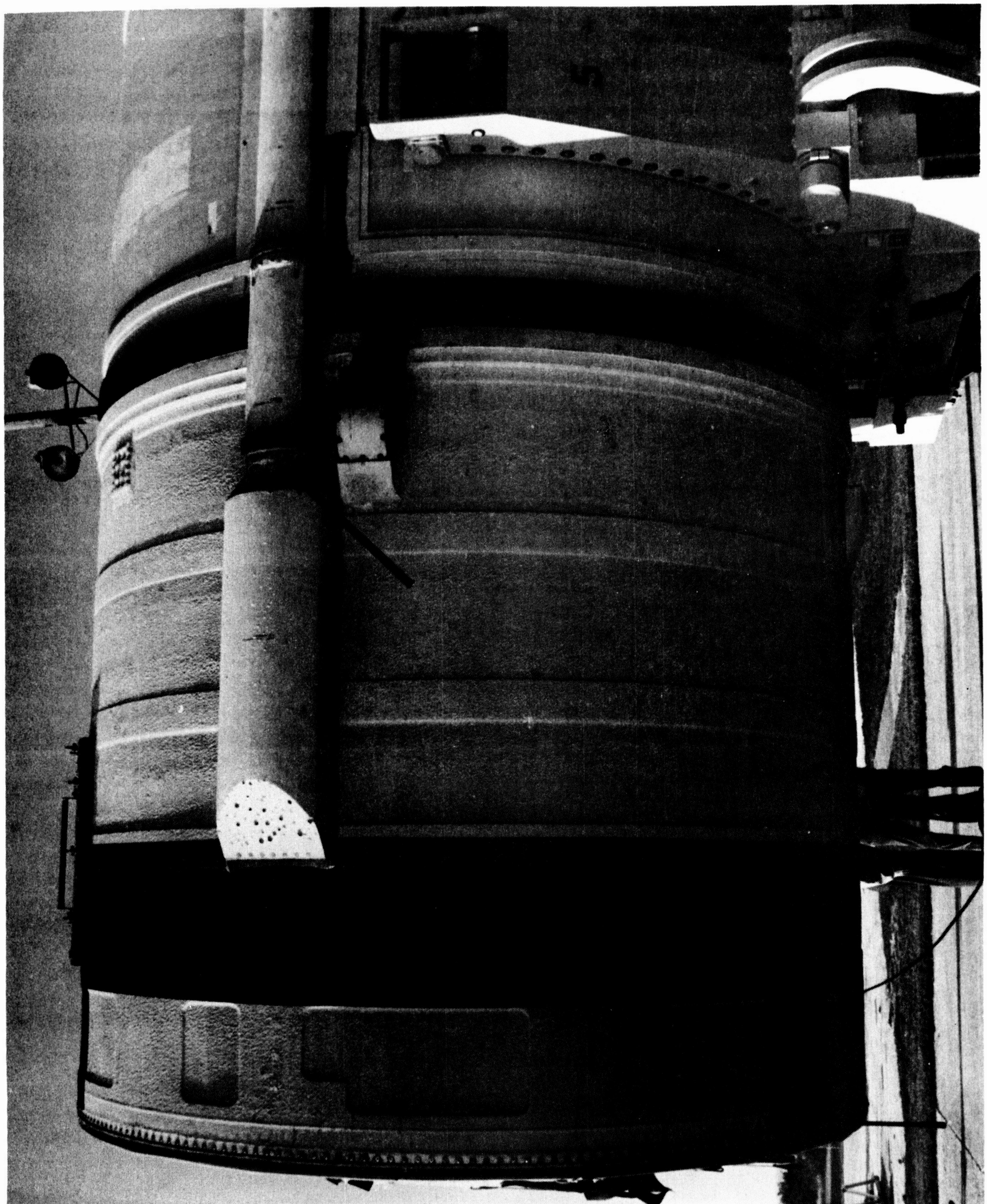
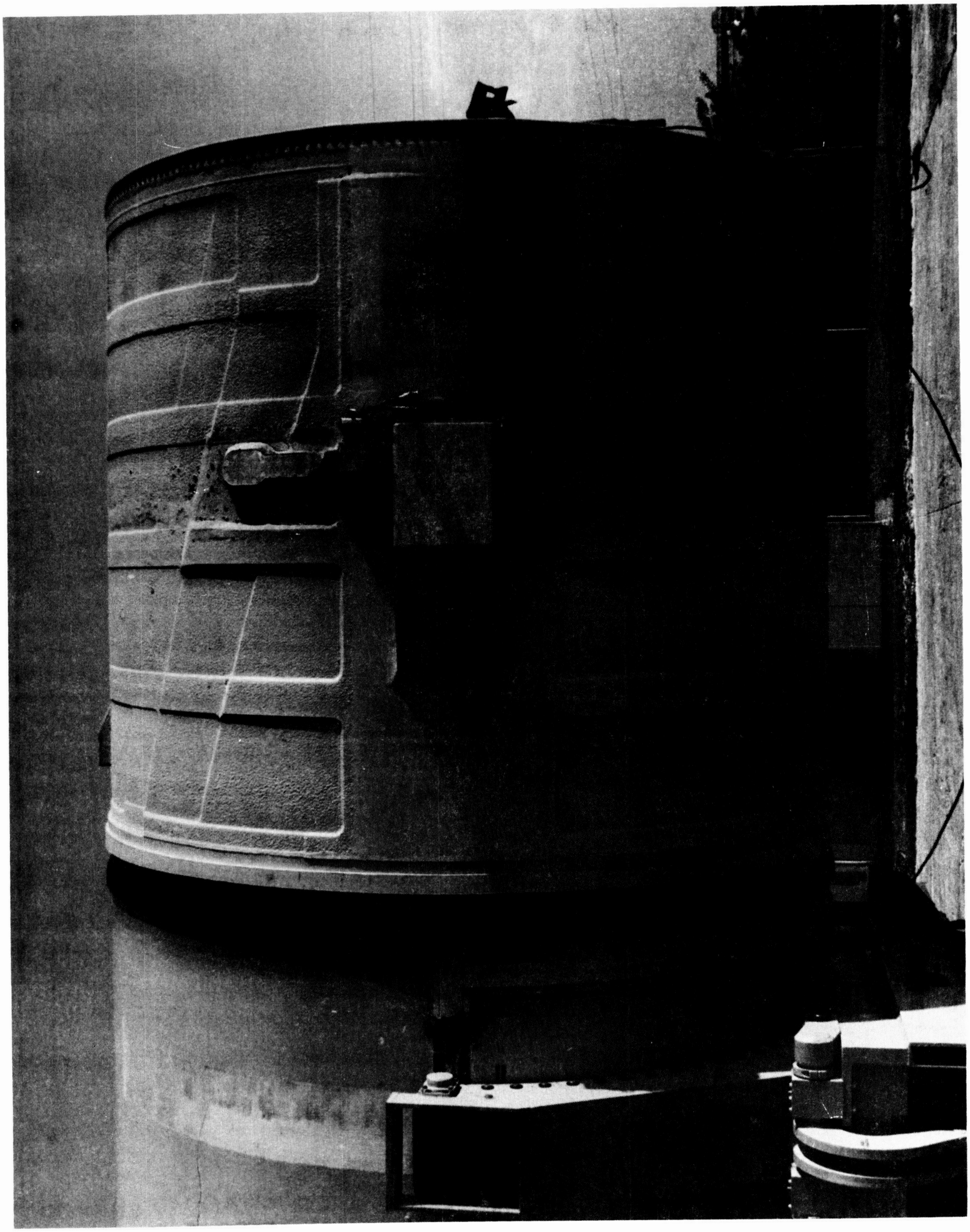


LH SRB FORWARD SKIRT. DFI CLOSEOUT MATERIAL INTACT.
K5NA NOT APPLIED TO SYSTEMS TUNNEL CLOSEOUT.



RH SRB **FORWARD** SKIRT. SHOWS SOME BLISTERING OF HYPALON **PAINT**.

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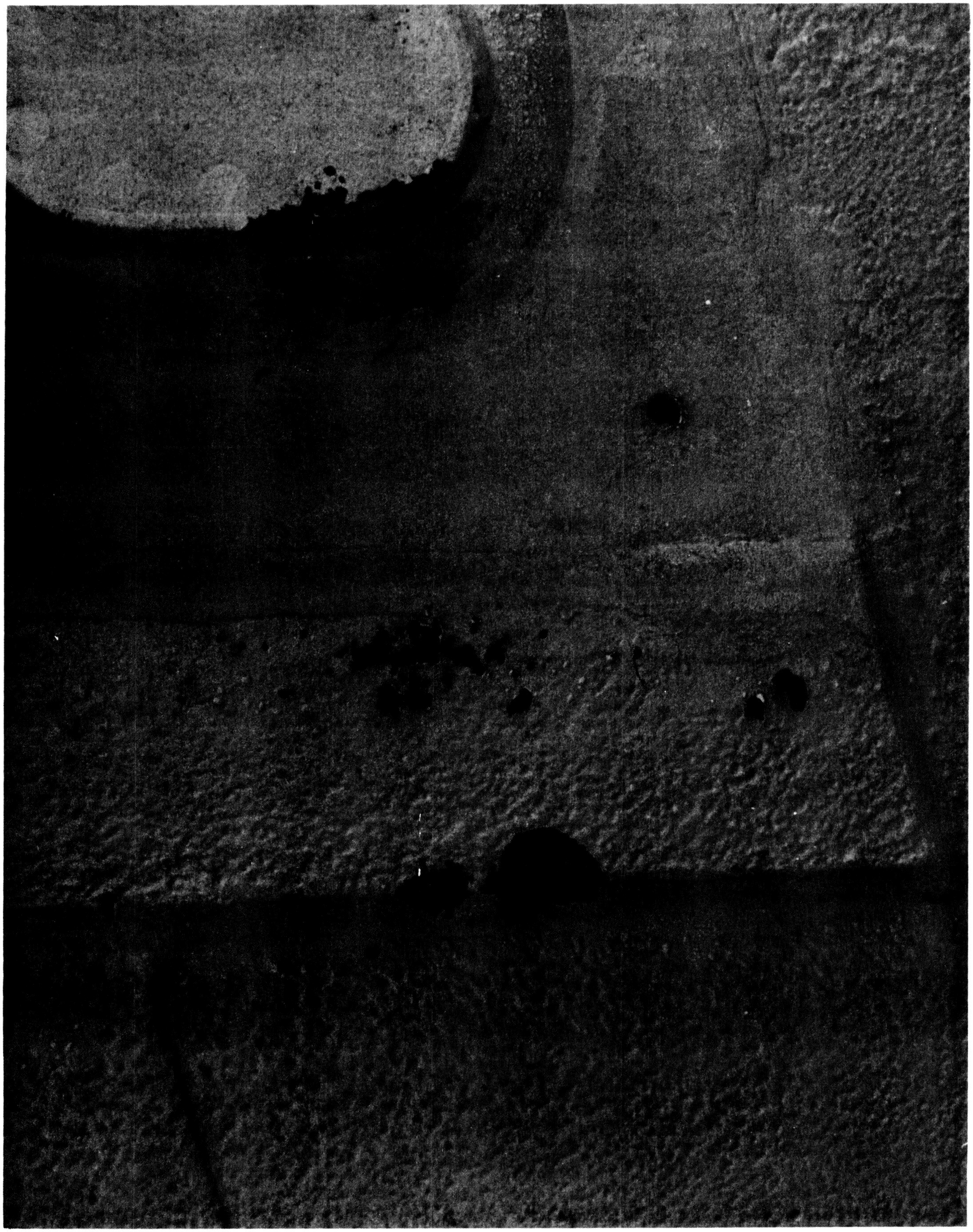

TPS DIVOTS AND BLISTERED HYPALON PAINT NEAR BANJO FITTING ON FORWARD SKIRT SHOW SIGNS OF ASCENT AEROHEATING

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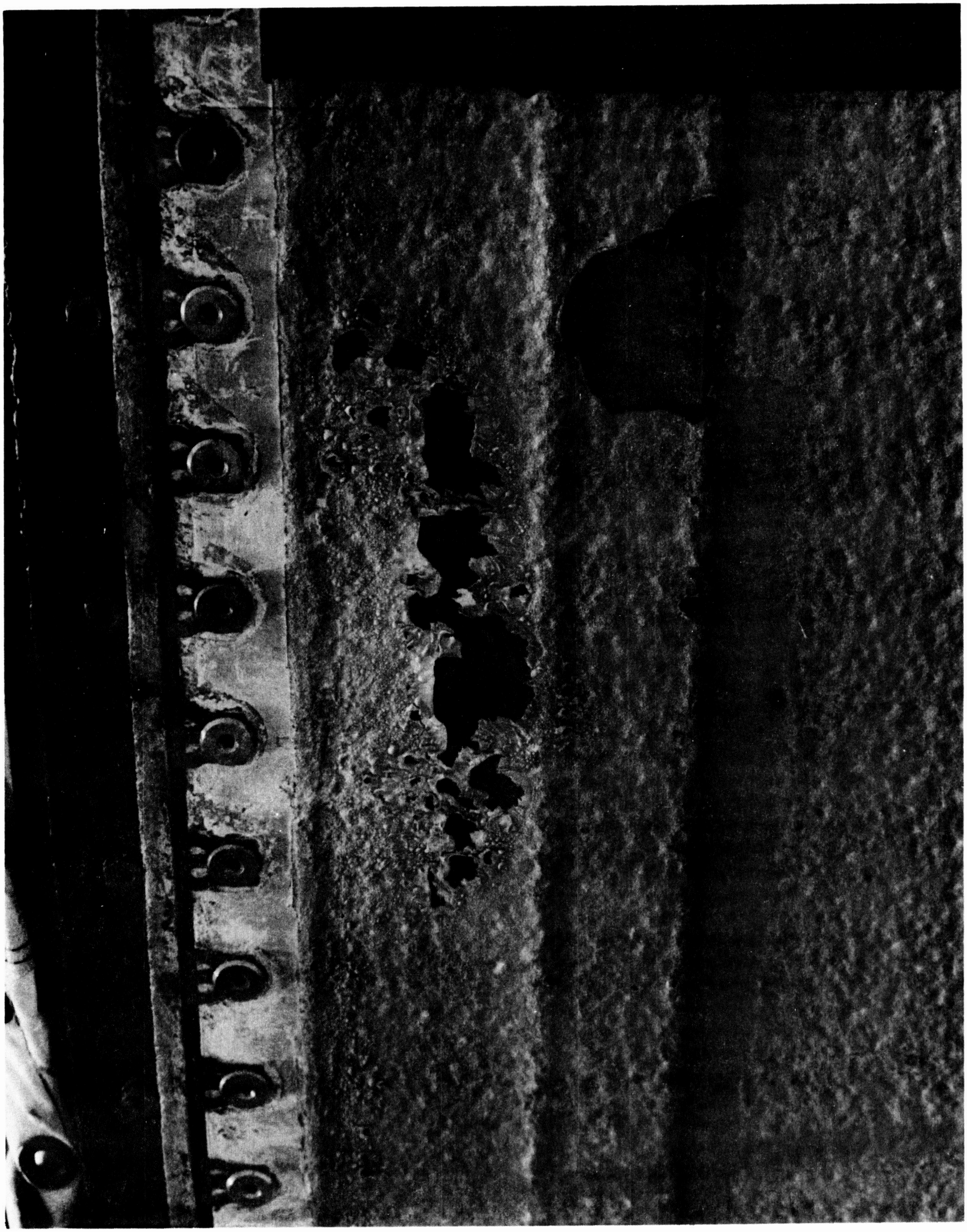
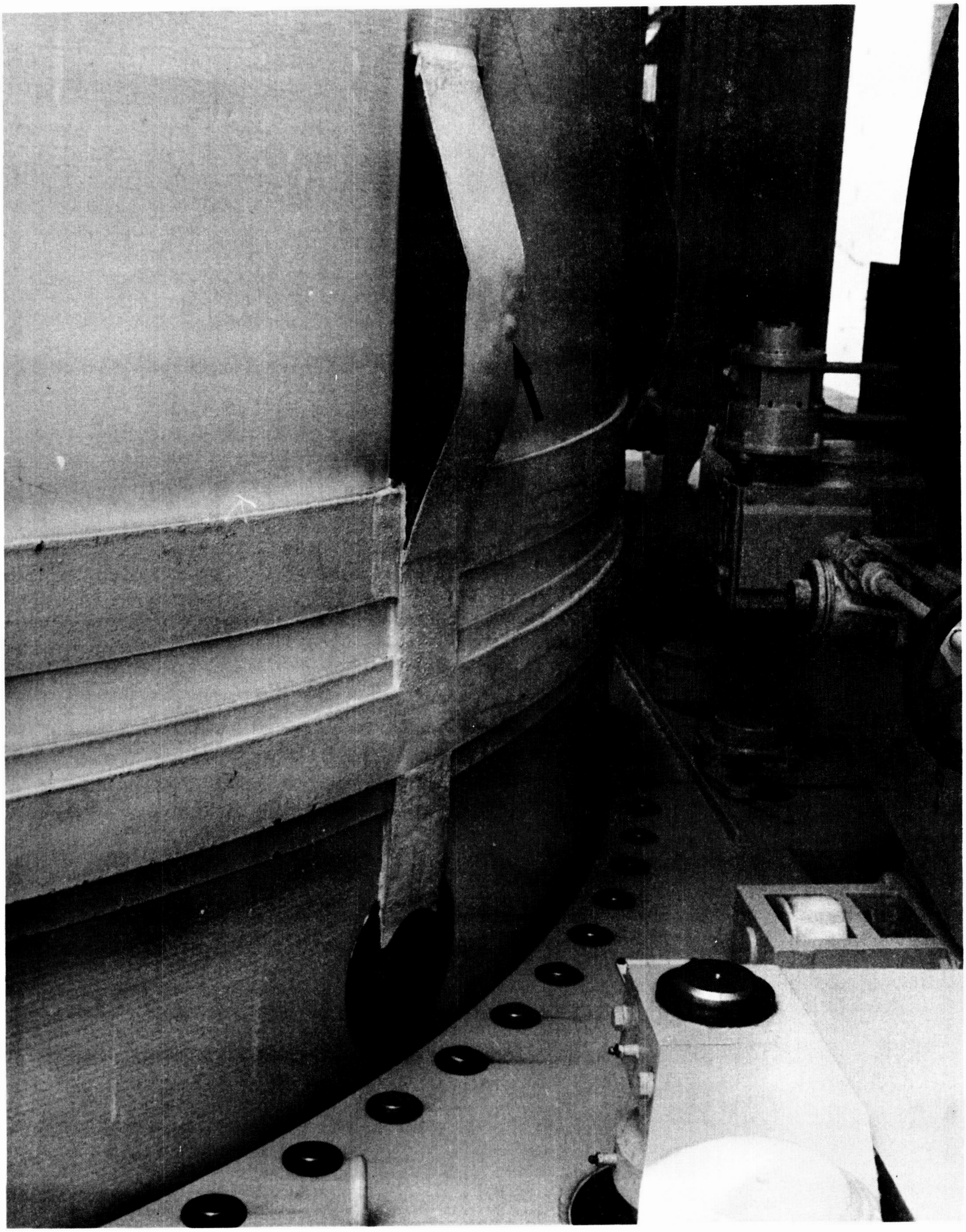


MISSING MSA-1 AND HYPALON PAINT **BLISTERING** NEAR LINEAR SHAPED CHARGE. BLISTER CRATERS SHOW SIGNS OF ASCENT AEROHEATING.



1-INCH DIAMETER DEBOND (NO MISSING MATERIAL) ON OUTBOARD FACE OF THE PRESSURE TRANSDUCER CORK RAMP ON THE LH FWD SRB SEGMENT

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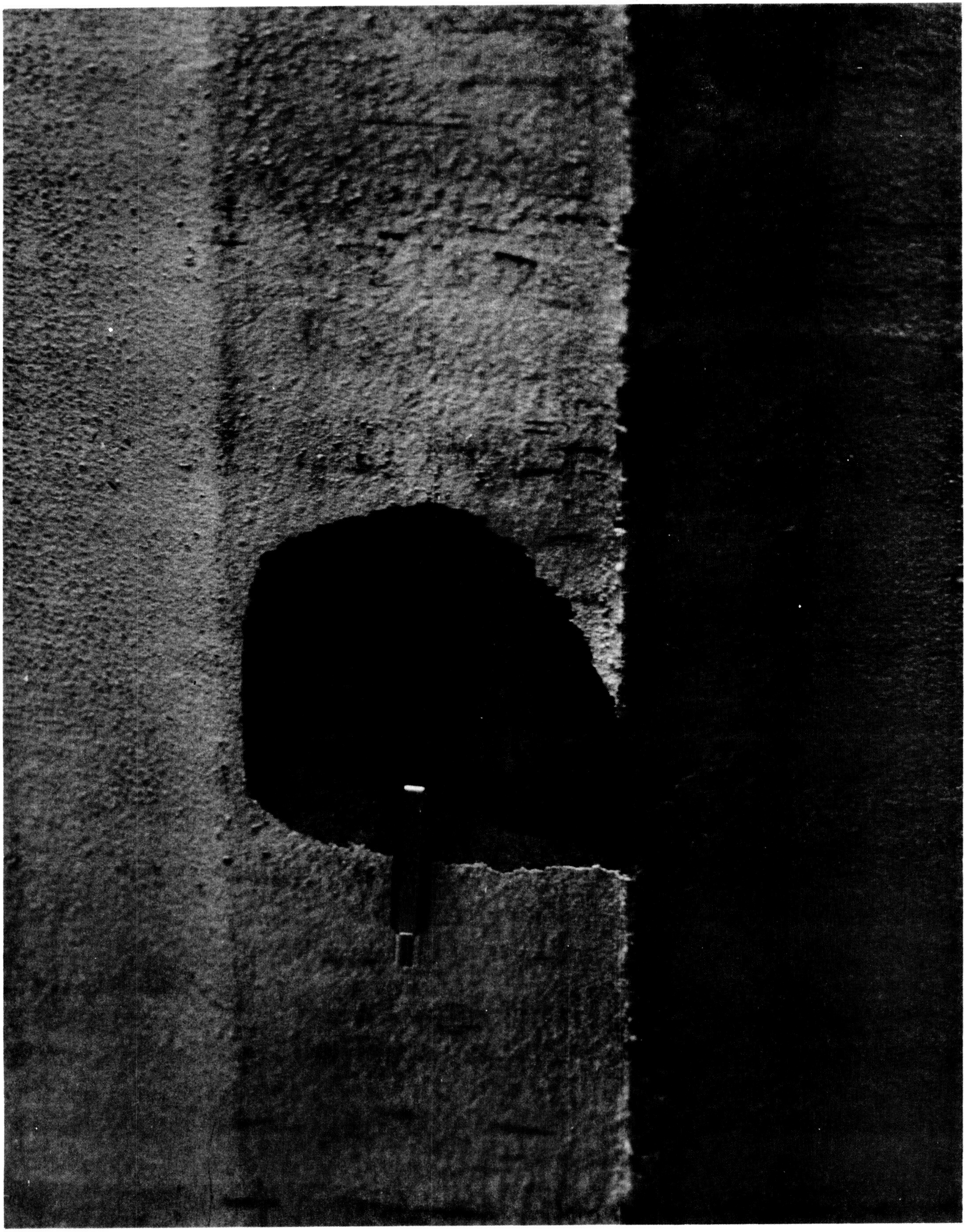
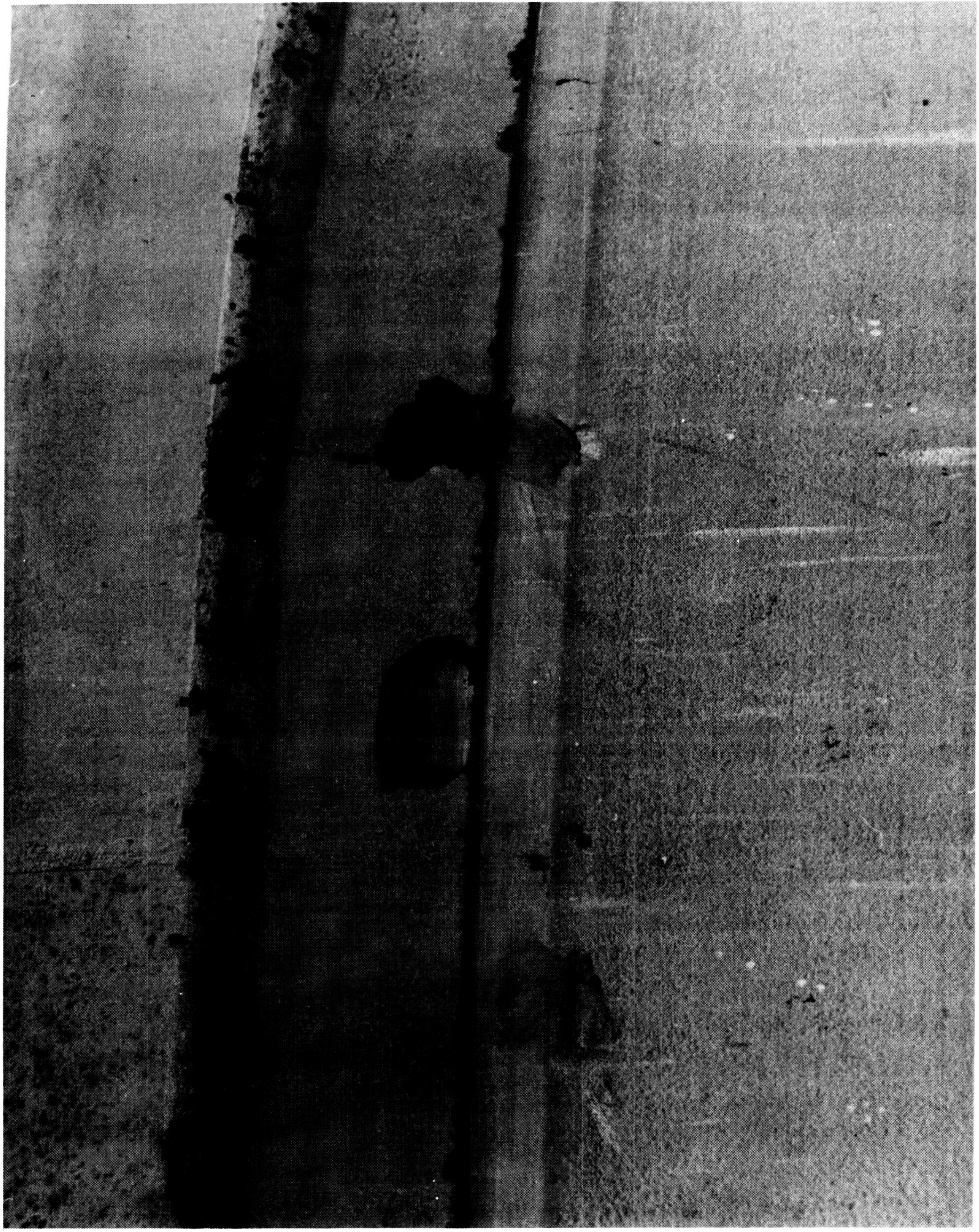


3.5-INCH DIAMETER DIVOT IN THE RH SRB CENTER FIELD JOINT CLOSEOUT AT 185°



RIGHT DFI CORK DIVOT SHOWS SIGNS OF ASCENT AEROHEATING.
LEFT DIVOT SHOWS IMPROPER BONDING AND CAME OFF AT WATER IMPACT.

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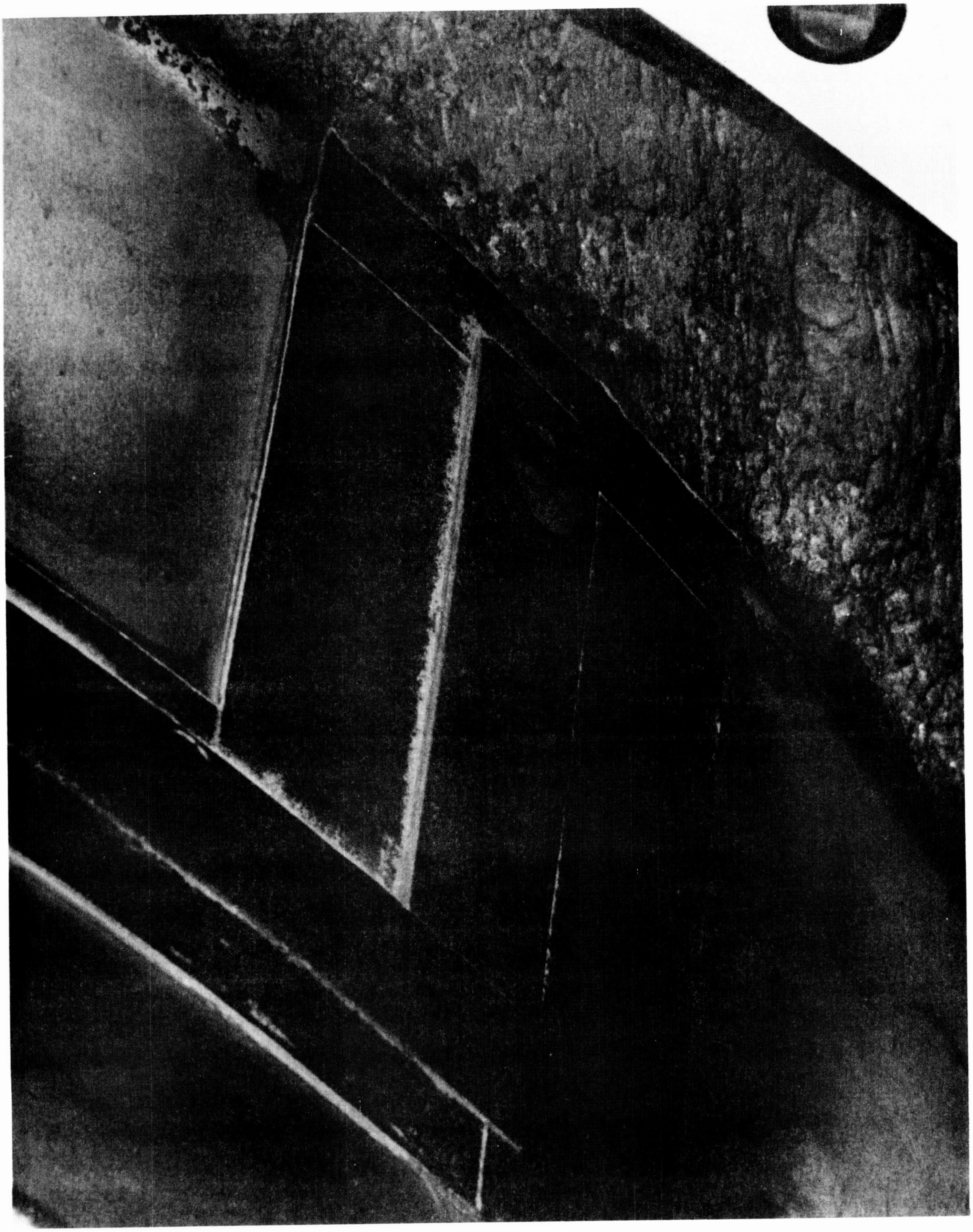
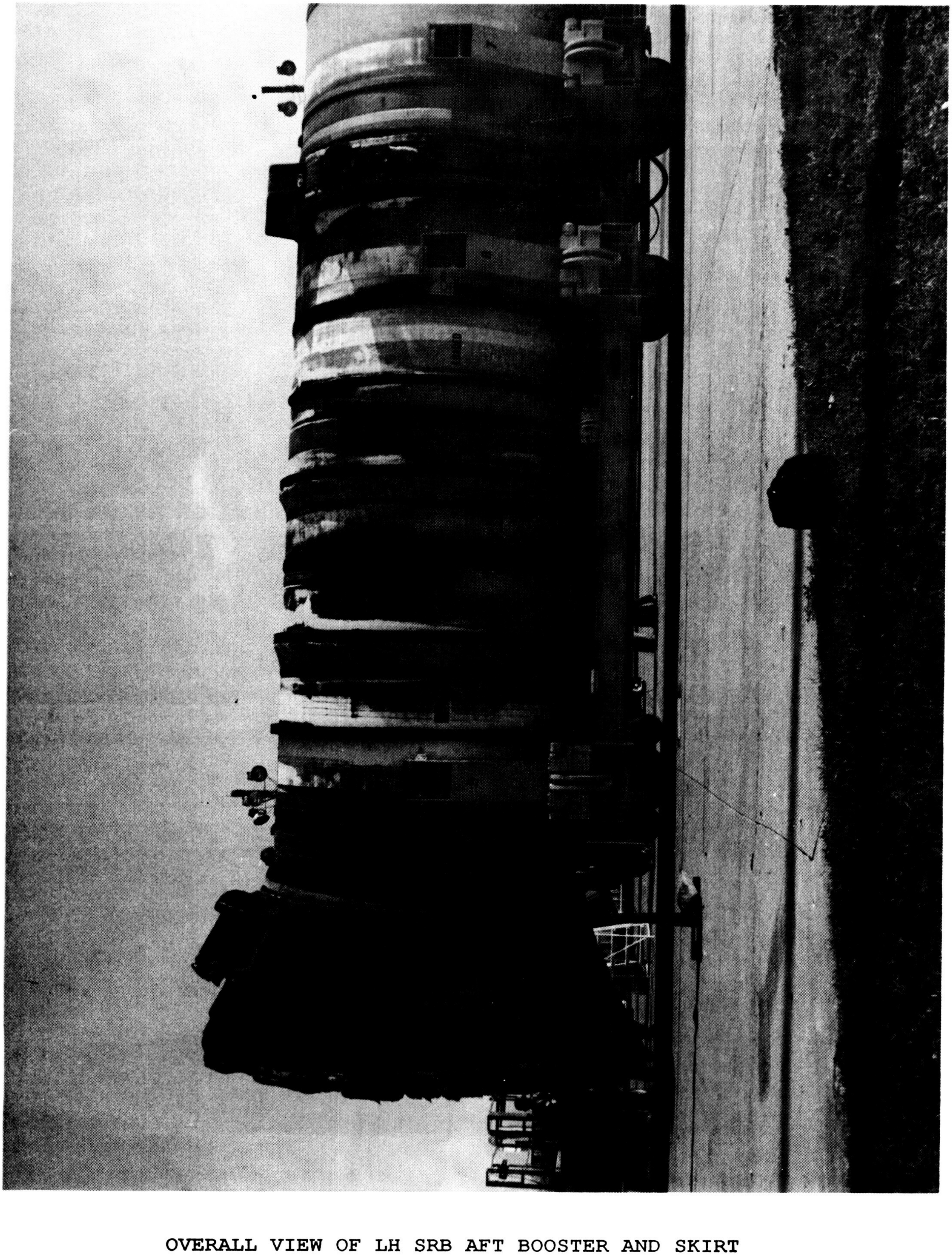
MISSING DFI CAP CORK FROM LH SRB AFT FIELD JOINT



DIVOT IN DFI CORK ON RH AFT BOOSTER NEAR AFT FIELD JOINT



OVERALL VIEW OF LH SRB AFT BOOSTER AND SKIRT

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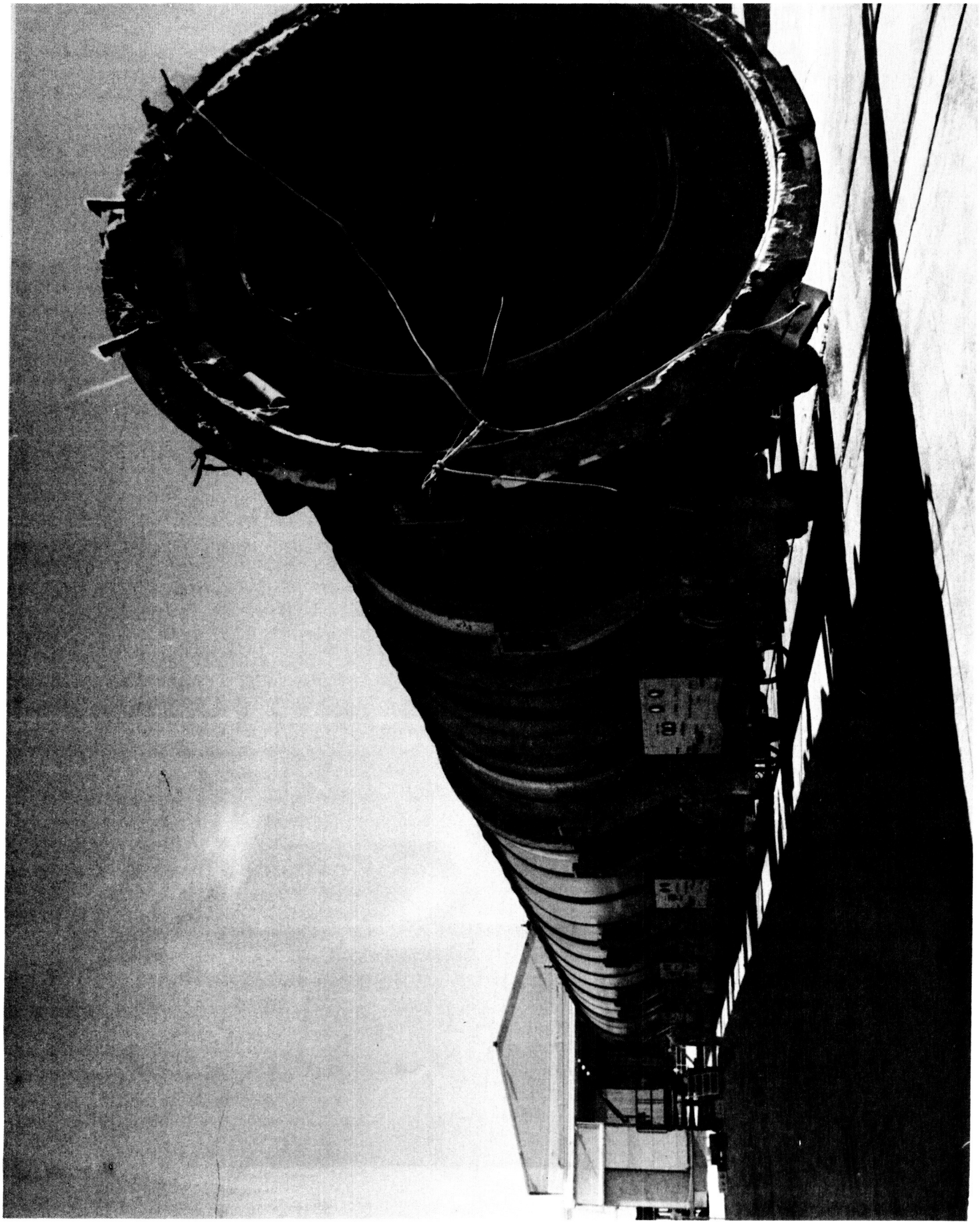

OVERALL VIEW OF RH SRB AFT BOOSTER AND NOZZLE

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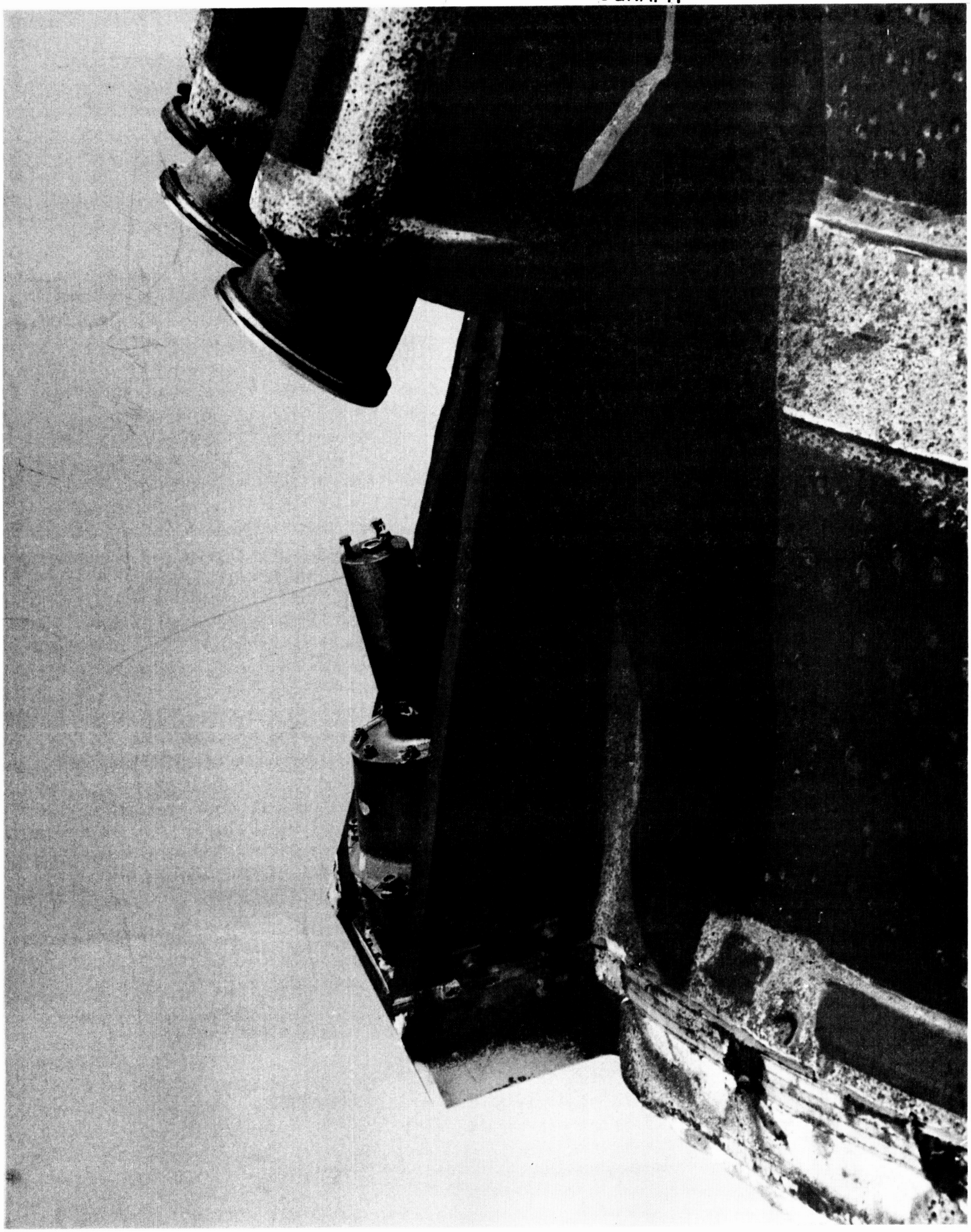
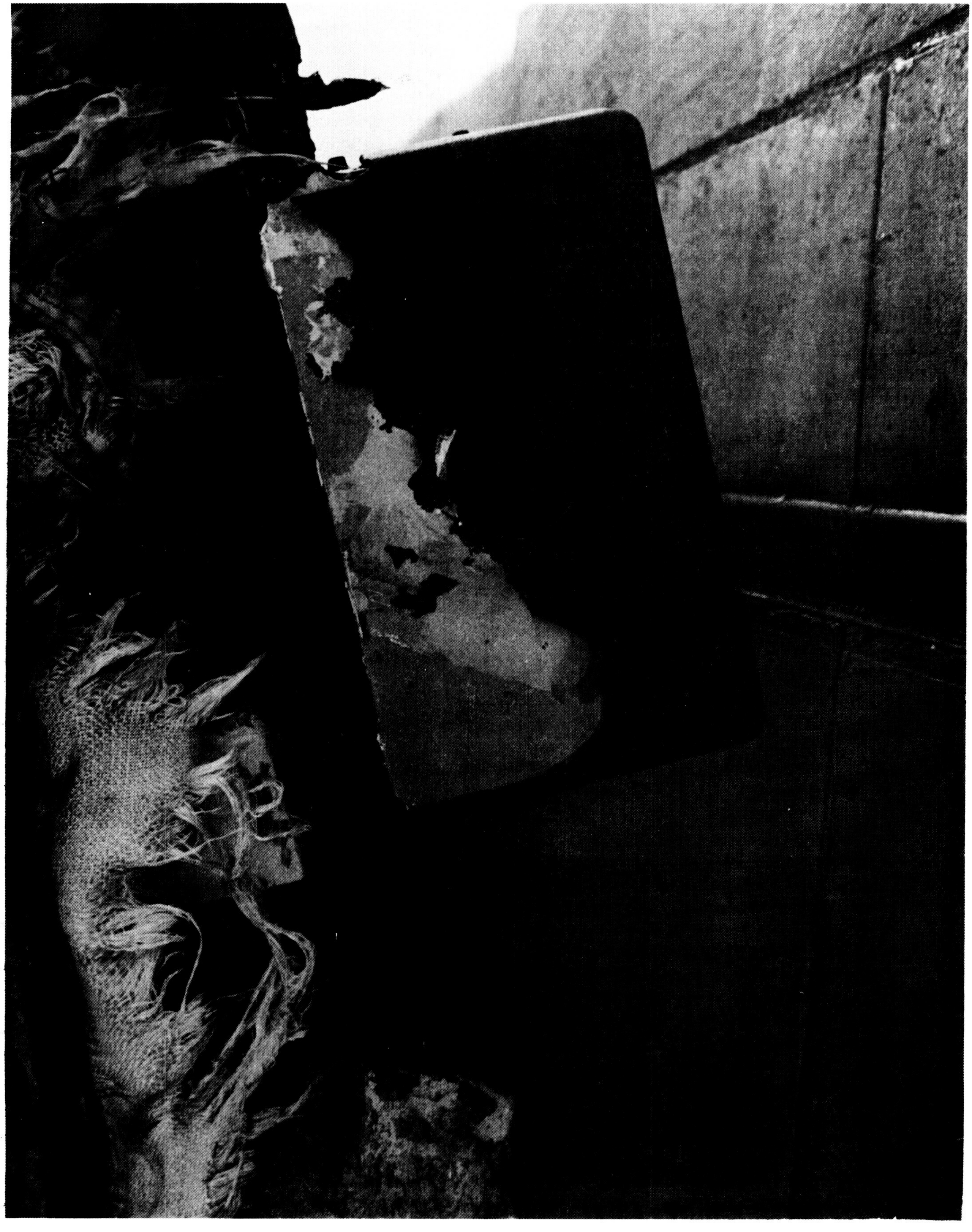


ALL AFT SKIRT DEBRIS CONTAINERS AND ATTACHING BOLTS WERE INTACT. LOCKWIRE HAD MELTED OR BROKEN ON ALL +Z CONTAINERS.



MISSING EPON SHIM MATERIAL FROM AFT SKIRT FOOT

9.0 ORBITER POST LANDING DEBRIS ASSESSMENT

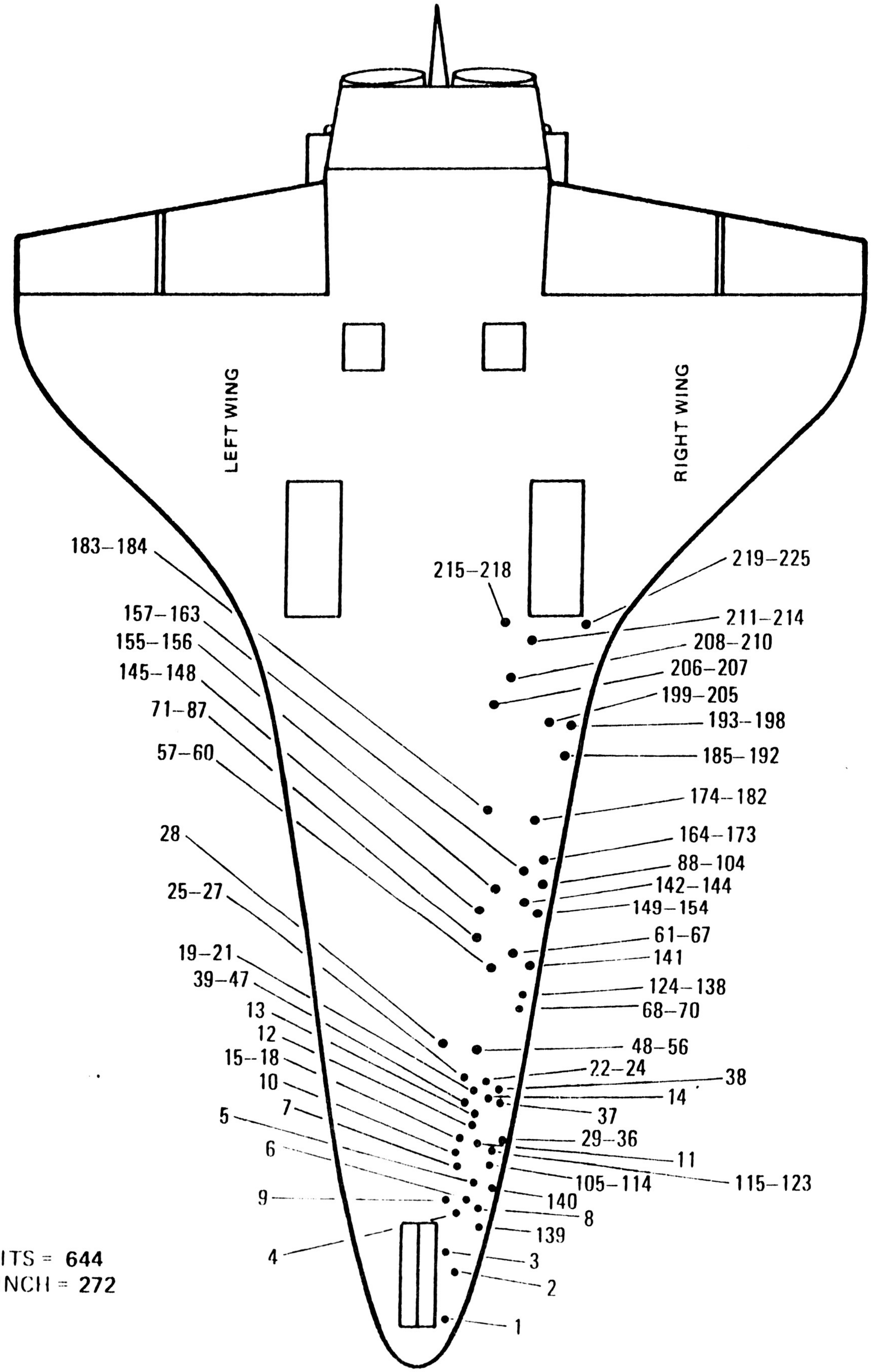
A detailed Post Landing Inspection of OV-104 was conducted December 6-7, 1988, at Dryden (EAFB) on Lakebed Runway 17L and in the Mate/Demate Device (MDD) to identify debris impacts, damage caused, and if possible, debris sources. The Orbiter sustained a total of 707 hits, of which 298 had a major dimension of one inch or greater. Based on the number of hits one inch and greater, and the severity of damage as judged from length, depth, and loss of tile surface, this flight had the most extensive Orbiter TPS damage to date.

The runway was in excellent condition. Debris picked up during the pre-landing inspection was considerably less than prior to the STS-26R mission, which used the same runway. The Orbiter touched down right of the centerline with the RH MLG contacting the runway a short distance prior to LH MLG touchdown. The Orbiter continued to roll slightly right of the centerline until approximately 200 yards before wheel stop, at which time the vehicle moved to the left and was positioned nearly over the centerline at wheel stop. Orbiter roll distance was 7381 feet.

The post landing walkdown of Runway 17L was performed at L+1 hour. A piece of the outboard-forward corner tile from the RH landing gear door was found near the runway approach threshold, near a point where the landing gear door was opened. The tile corner was originally a 3 1/2" x 4" piece, but had broken into several smaller pieces after impacting the runway. Three tile gap fillers and part of a fourth were found along the Orbiter track. A piece of fiberglas yarn from the engine heatshield insulation was also found.

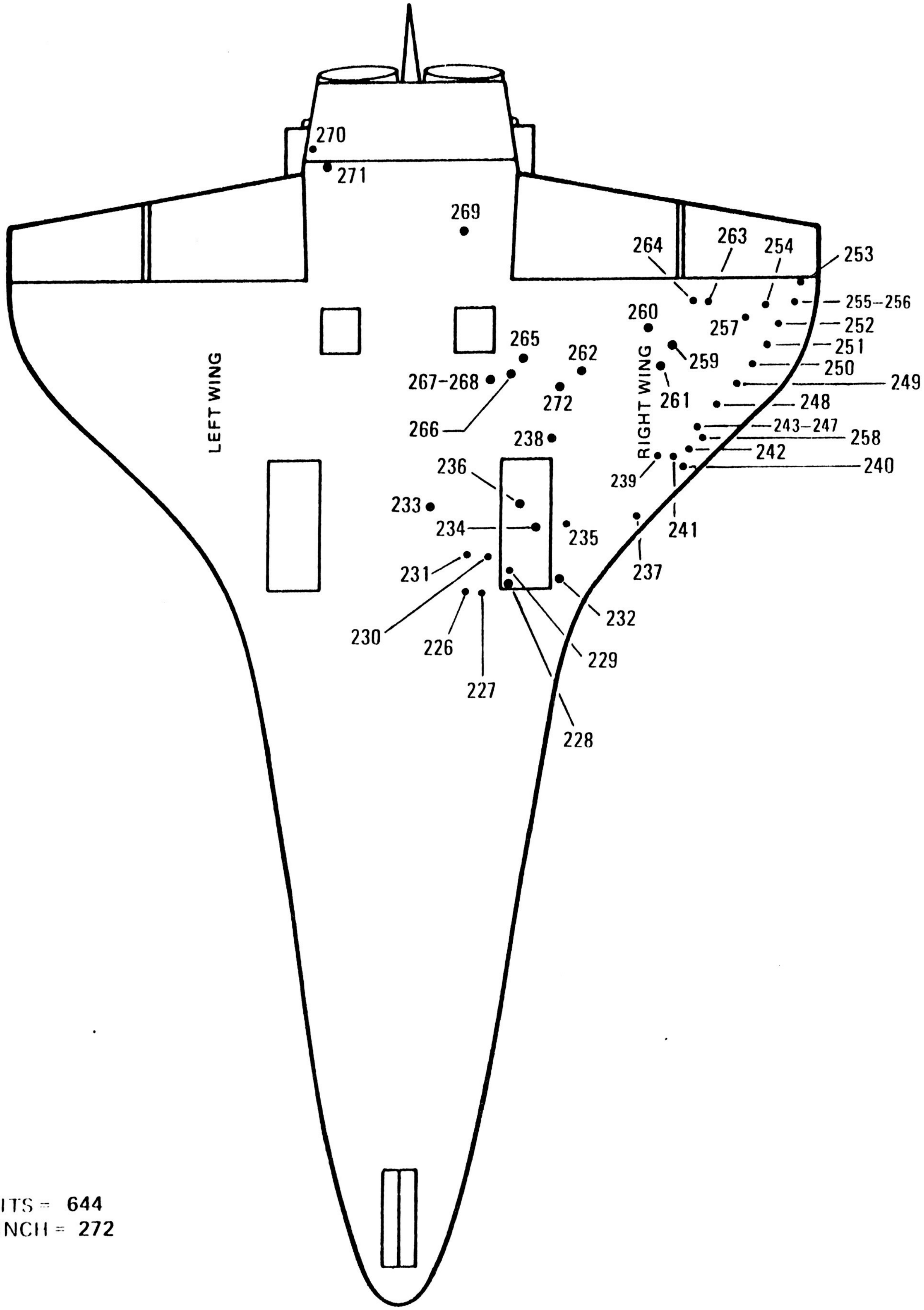
The Orbiter RH lower surface received what is assessed to be the most severe tile damage to date (270 damage sites greater than 1-inch). The area of concern was concentrated primarily outboard of a line from the bipod attachment to the ET-Orbiter LO2 umbilical (Figures 17, 18, and 19). A tile was missing from a damage site on the RH side slightly forward of the L-Band antenna. Substrate heating in this area and underneath an adjacent tile was apparent. The SIP was scorched, which occurs at 550 deg F. Subsequent substrate tests determined the aluminum structure had been subjected to 550-575 deg F temperatures for a 15 minute period. Adjacent tiles on both sides showed damage from a common source. Several damage sites exhibited wide streaks (greater than 2 inches) over several tiles with shallow penetration. This type of damage is characteristic of that known to be caused by low density material such as SOFI (2.6 lbs per cubic ft). Numerous other damaged areas were relatively long, narrow streaks with deep gouges. This type of damage is usually caused by higher density materials such as ice and other TPS materials.

FIGURE 17. Orbiter Lower Surface



TOTAL HITS = **644**
HITS $\geq$ 1 INCH = **272**

FIGURE 18. Orbiter Lower Surface



TOTAL HITS = 644
HITS ≦ 1 INCH = 272

FIGURE 19. Tile Hits on Orbiter Lower Surface

LOCATION #	SIZE L x W x D (in.)	LOCATION #	SIZE L x W x D (in.)
1	1/2 x 1 1/4 x 1/8	26	7 x 3 x 1/4
2	8 x 2 1/2 x 1 1/2	27	1 x 3/4 x 1/8
3	2 1/2 x 2 x 1/4	28	2 x 1 1/2 x 1/4
4	1 1/4 x 3/4 x 1/4	29	5 x 2 x 1/4
5	2 1/2 x 1/2 x 1/8	30	2 1/2 x 1 x 1/16
6	3 1/2 x 1/4 1/4	31	3 x 3/4 x 1/16
7	1 1/4 x 1 1/2 x 1/8	32	1 x 1 x 1/16
8	1 x 5/8 x 1/16	33	3 x 1 x 1/4
9	1 x 4 x 1/4	34	1 x 1/2 x 1/8
10	3 x 1 1/4 x 1/16	35	3 x 3/4 x 1/8
11	16 x 2 1/2 x 2 1/2	36	1 1/2 x 1 x 1/16
12	1 1/2 x 1 1/2 x 2	37	7 x 4 x 1/2
13	2 x 3/4 x 1/4	38	8 x 1 1/2 x 1/2
14	9 x 3 x 1/2	39	4 x 3 1/2 x 3/8
15	4 x 5/8 x 1/2	40	1 1/2x 3/4 x 1/16
16	2 x 1 1/4 x 1/16	41	2 x 1 1/4 x 1/4
17	3 x 3/4 x 1/16	42	2 x 1/2 x 1/4
18	1 x 3/8 x 1/4	43	4 x 5/8 x 3/4
19	2 x 1 1/4 x 1/4	44	1 x 3/8 x 1/16
20	1 x 3/4 x 1/16	45	2 1/2 x 1 x 1/4
21	2 x 1 1/4 x 1/16	46	1 x 1/2 x 1/4
22	3 x 3/4 x 1/16	47	3 x 1 x 1 1/4
23	1 1/2x 1 1/4 x 1/16	48	7 x 2 x 1/4
24	2 x 1 1/4 x 1/4	49	11 x 1 x 1/4
25	2 x 1 x 1/4	50	3 x 3/4 x 1/2

LOCATION #	SIZE L x W x D (in.)	LOCATION #	SIZE L x W x D (in.)
51	3 1/2 x 1 x 1/8	76	16 x 3 x 1/2
52	1 x 5/8 x 1/4	77	1 x 1/2 x 1/16
53	2 x 5/8 x 1/4	78	3 x 1/2 x 1/4
54	3 x 1/2 x 1/16	79	1 x 1 x 1/16
55	1 1/2 x 3/4 x 1/8	80	3 x 1 x 1/4
56	3 x 3/4 x 1/4	81	1 x 1/2 x 1/16
57	8 x 3 x 3/8	82	6 x 3/4 x 1/4
58	2 x 5/8 x 1/4	83	2 x 1/2 x 1/4
59	3 x 1/2 x 3/4	84	1 x 1/2 x 1/4
60	2 1/2 x 3/8 x 1/8	85	1 x 1/4 x 1/16
61	3 x 3 x 3/8	86	9 x 2 x 1/16
62	2 x 3/8 x 1/4	87	5 x 1 1/2 x 1/4
63	4 x 1/2 x 1/2	88	1 1/2 x 3/4 x 3/8
64	3 x 1 x 1/2	89	2 x 1 1/4 x 1/2
65	5 x 3/4 x 1/8	90	7 x 3 x 1
66	2 x 3/8 x 1/4	91	1 x 1 x 1/2
67	1 1/2 x 1 x 1/4	92	3 x 1/2 x 1/8
68	3 x 1 x 1/8	93	1 x 3/4 x 1/8
69	1 x 1 x 1/16	94	4 x 3/4 x 1/2
70	2 1/2 x 1/2 x 1/4	95	4 x 5/8 x 1/2
71	8 x 2 x 3/4	96	4 x 1 1/2 x 1/2
72	3 x 1/2 x 1/4	97	2 1/2 x 1 1/4 x 1/2
73	2 x 1/2 x 1/4	98	2 x 1 1/4 x 1/16
74	7 x 3/4 x 1/4	99	2 x 1/2 x 1/16
75	1 1/2 x 3/4 x 1/4	100	1 1/4 x 1/2 x 3/8

LOCATION #	SIZE L x W x D (in.)	LOCATION #	SIZE L x W x D (in.)
101	1 1/2 x 1/2 x 1/8	126	2 1/2 x 3/4 x 3/8
102	1 x 1/2 x 1/16	127	3 x 1/2 x 1/8
103	4 x 1 x 1/16	128	3 x 1 1/2 x 3/4
104	1 x 3/4 x 1/16	129	2 x 1 x 1/4
105	1 1/4 x 1/2 x 1/16	130	2 1/2 x 1 1/4 x 3/8
106	1 1/2 x 3/4 x 1/16	131	1 x 1/2 x 1/16
107	7 x 4 x 1/8	132	1 x 3/8 x 1/4
108	4 x 1 1/2 x 1/4	133	6 x 2 1/2 x 1
109	1 1/2 x 3/4 x 1/4	134	2 1/2 x 1 x 5/8
110	6 x 1 x 1/4	135	1 1/2 x 5/8 x 1/4
111	4 x 1 x 1/4	136	2 x 1 1/4 x 1/16
112	1 1/2 x 3/4 x 1/2	137	1 x 3/4 x 1/16
113	7 x 3 x 1/2	138	1 x 3/4 x 1/16
114	3 x 3/4 x 1/16	139	2 x 3 x 1/8
115	2 1/2 x 1/2 x 1/4	140	1 1/2 x 1/2 x 1/4
116	9 x 1 1/2 x 1/4	141	22 x 5 x 3/4
117	1 1/2 x 1/2 x 1/8	142	7 x 3 1/2 x 1/2
118	2 x 1 x 3/4	143	3 x 1 1/2 x 1/2
119	3 1/2 x 3/4 x 1/2	144	4 x 3/4 x 1/2
120	1 x 3/8 x 1/8	145	6 x 1 x 3/8
121	3 x 1 x 1/8	146	1 x 3/4 x 1/8
122	2 1/4 x 1 1/4 x 1/2	147	3 1/2x 1 3/4x 1 1/4
123	2 x 3 x 1/2	148	1 x 1/2 x 3/8
124	16 x 6 x 1	149	6 x 5/8 x 1/4
125	7 x 1 x 3/8	150	3 1/2 x 1 1/4 x 3/4

LOCATION #	SIZE L x W x D (in.)	LOCATION #	SIZE L x W x D (in.)
151	3 1/2 x 3/4 x 3/8	176	4 x 1/2 x 1/2
152	1 1/4 x 5/8 x 3/8	177	2 x 1 x 1/16
153	4 x 3/4 x 1/2	178	6 x 1 x 3/8
154	3 1/2 x 5/8 x 1/4	179	4 1/2 x 5/8 x 5/8
155	3 x 3/4 x 1/8	180	1 1/2 x 1/2 x 1/8
156	2 1/2 x 1 1/2 x 1/8	181	1 x 3/4 x 1/16
157	2 x 1 1/4 x 1/2	182	2 x 5/8 x 1/16
158	2 x 3/4 x 3/8	183	18 x 1 x 3/4
159	2 x 3/8 x 3/8	184	2 x 1 x 1/16
160	4 x 1 x 1/8	185	1 1/2 x 1/2 x 3/8
161	3 x 1/2 x 1/16	186	5 x 2 1/2 x 1/16
162	1 1/2 x 3/4 x 1/16	187	1 x 3/8 x 1/16
163	1 1/2 x 3/8 x 1/16	188	2 x 5/8 x 3/8
164	2 x 3/4 x 1/16	189	5 x 2 1/2 x 1
165	1 1/4 x 1 x 1/2	190	1 x 3/4 x 1/2
166	3 1/2 x 1 1/2 x 1/2	191	3 1/2 x 1/2 x 3/8
167	1 3/4 x 3/4 x 3/8	192	2 x 3/4 x 1/16
168	2 1/4 x 3/4 x 1/16	193	1 1/2 x 1/2 x 1/4
169	1 1/4 x 3/8 x 1/16	194	4 x 1 x 3/8
170	2 1/2 x 1/2 x 3/8	195	3 x 1 1/4 x 1/4
171	1 1/4 x 1/2 x 3/8	196	5 1/2 x 1 1/2 x 3/8
172	3 1/2 x 1 1/2x 1/16	197	1 1/2 x 1 1/4 x 1/2
173	18 x 3 1/2 x 1/2	198	1 x 1/2 x 1/4
174	3 x 1 1/2 x 3/8	199	2 1/2 x 1/2 x 3/8
175	2 x 3/8 x 3/8	200	1 1/2 x 1/2 x 3/8

LOCATION #	SIZE L x W x D (in.)	LOCATION #	SIZE L x W x D (in.)
201	3 1/2 x 1 x 3/8	226	1 x 3/8 x 1/8
202	3 1/2 x 1 1/2x 1/16	227	1 1/2 x 3/8 x 1/8
203	3 x 5/8 x 3/8	228	2 x 1/2 x1/2
204	1 x 1/2 x 1/16	229	1 x 3/8 x 1/4
205	1 1/2 x 1/2 x 1/16	230	3 x 1 x 3/16
206	1 1/2 x 1/2 x 3/8	231	5 x 3/4 x 1/4
207	1 1/2 x 1/2 x 1/16	232	1 1/2 x 3/4 x 1/4
208	3 x 1 x 3/4	233	1 x 3/8 x 1/8
209	2 1/2 x 5/8 x 1/16	234	3 x 1 1/4 x 1/2
210	4 x 3/4 x 1/2	235	3 x 3/4 x 1/4
211	4 x 1 1/4 x 3/4	236	6 x 3/4 x 1/2
212	1 x 3/8 x 1/16	237	1 x 1/2 x 1/4
213	1 x 1/2 x 3/8	238	1 1/2 x 5/8 x 3/16
214	1 x 3/8 x 1/16	239	1 x 1/2 x 1/8
215	1 x 1/2 x 1/16	240	1 1/4 x 3/8 x 1/8
216	3 1/2 x 2 1/2 x 1/8	241	1 1/4 x 1/2 x 1/8
217	2 x 3/4 x 1/2	242	12 x 1 x 3/8
218	3 x 1 x 3/4	243	1 x 3/8 x 1/8
219	1 1/4 x 3/8 x 3/8	244	2 x 3/8 x 3/16
220	1 3/4 x 3/4 x 1/8	245	1 x 3/8 x 1/8
221	5 1/2 x 5/8 x 1/2	246	6 x 1/2 x 1/4
222	1 1/2 x 1/2 x 3/8	247	3 x 1/2 x 1/4
223	2 1/2 x 1 x 1/2	248	1 1/2 x 3/4 x 1/8
224	1 1/2 x 3/4 x 1/16	249	1 1/4 x 3/8 x 1/8
225	2 x 5/8 x 1/16	250	3 x 1/4 x 1/8

LOCATION #	**SIZE** **L x W x D (in.)**
251	1 1/4 x 1/2 x 1/8
252	2 x 3/8 x 1/8
253	1 x 1/2 x 1/4
254	1 1/4 x 5/8 x 1/8
255	3 x 3/4 x 1/8
256	1 1/2 x 1/2 x 1/8
257	1 1/2 x 1/2 x 1/8
258	2 x 3/8 x 1/8
259	2 x 1/2 x 1/4
260	1 x 1/2 x 1/8
261	4 x 1/2 x 1/8
262	4 x 1 1/4 x 3/16
263	6 x 1 x 1/4
264	4 x 2 x 1/8
265	1 1/2 x 1/2 1/8
266	1 3/4 x 5/8 x 3/16
267	1 1/2 x 1 x 1/4
268	1 1/4 x 1/2 x 1/4
269	1 x 3/4 x 1/4
270	4 x 1 x 1 1/2
271	2 x 3/4 x 1/8
272	1 3/4 x 3/4 x 3/8

Only two damage sites greater than 1-inch were observed on the LH lower surface. This represents the lowest count of any previous missions. The body flap lower surface had two damage sites greater than 1-inch. The lower elevon surfaces had none.

The total count of lower surface hits was 644 with 272 hits greater than one inch.

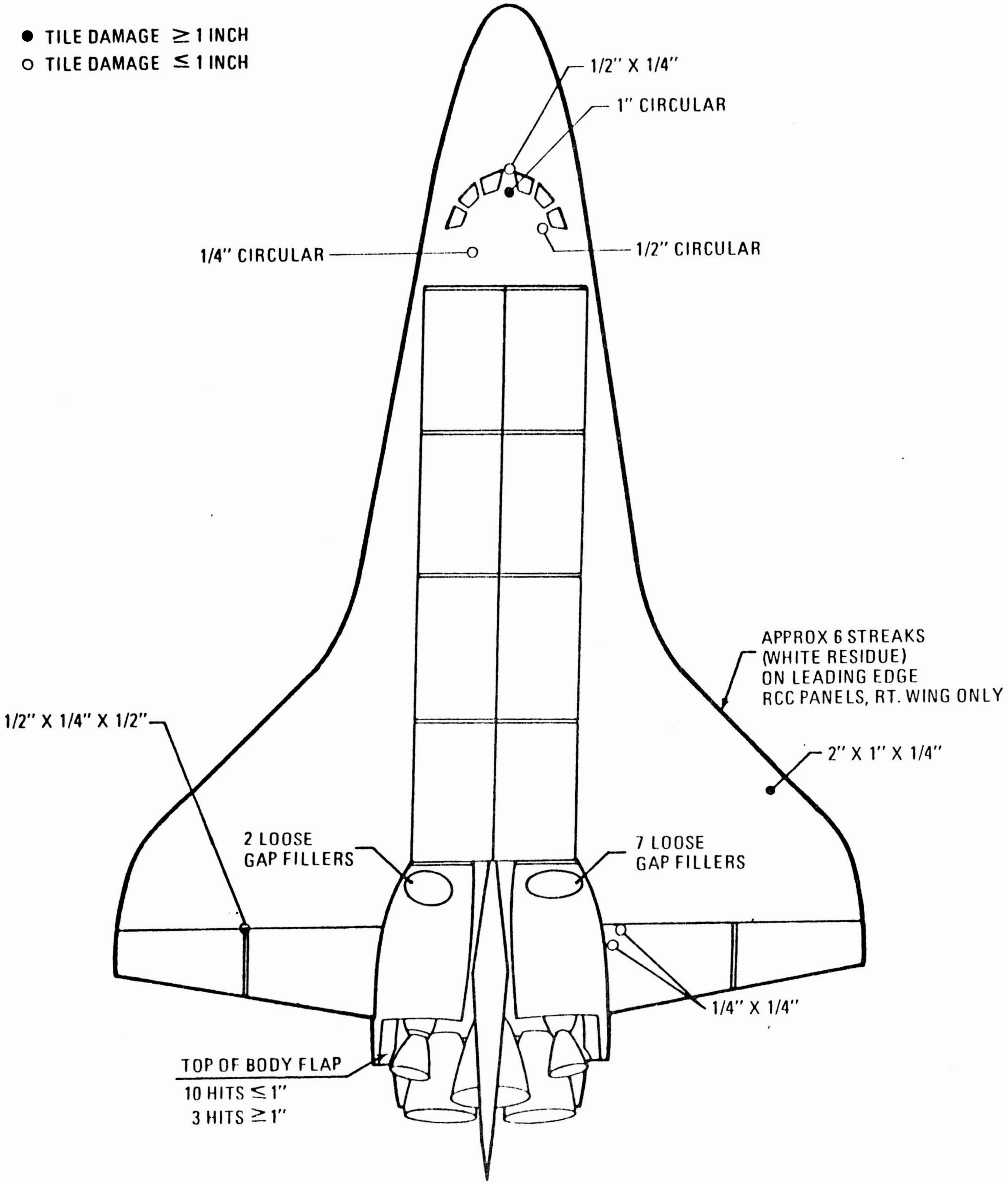
The upper nose surface exhibited only minor damage with two damaged sites greater than 1-inch. There was a 1 inch diameter hit above and between windows 3 and 4 (Figure 20).

Damage to the LH OMS pod was minimal with no hits greater than 1-inch (Figure 21). The RH OMS pod surface received 14 hits greater than 1-inch (Figure 22). There was an unusual 1/2" penetration into the AFRSI blankets on the RH side of the OMS pod. Dark foreign material in the hole was removed for analysis and determined to be MSA-1 with topcoat. This material is used on the SRB forward skirt assembly.

Four hits greater than 1-inch were observed on the RH side of the rudder speed brake.

A fiberglas carrier panel V070-396403-002 installed on the door which covers attach point #9 of the RH OMS pod was missing from its position midway along the lower outboard edge of the pod. Damage to the surrounding area (abrasion and impact signs on the blanket immediately aft of the missing panel location) and launch photography confirm the panel was lost during ascent. However, there was no evidence of heat related damage to the door or to the surrounding structure. A closer inspection in the MDD revealed that the sleeve bolts and the retaining rings were still attached to the door, but no flat washers or carrier panel fragments were present. Investigation by PR determined the torque values were acceptable at 5 of 6 locations and slightly low at position 5. Fastener-to-structure measurements show that all fastener heads were embedded into the panel due to the lack of flat washers and that the lower leading edge corner fastener was torqued completely through the panel. The fasteners, removed and measured for length, were shorter than the drawing requirement. Measurement of the retaining rings confirmed that the improper type had been installed. The purpose of the retaining ring in this type of fastener is to permanently secure the sleeve bolt to the panel. Omission of the flat washers greatly reduced the fastener bearing area on the panel and caused the fasteners to be torqued into and through the panel. This condition was aggravated by the incorrect grip length, which allowed the fasteners to be torqued into the panel rather than shanking out. The incorrect retaining rings prevented the panel from seating flush to the door and may have allowed airflow to intrude and lift the panel. The carrier panel had been installed on the OMS pod per a job card that called out the correct hardware. However, the installation of the captive fasteners into the panel had been done to an

FIGURE 20. Orbiter Upper Surface



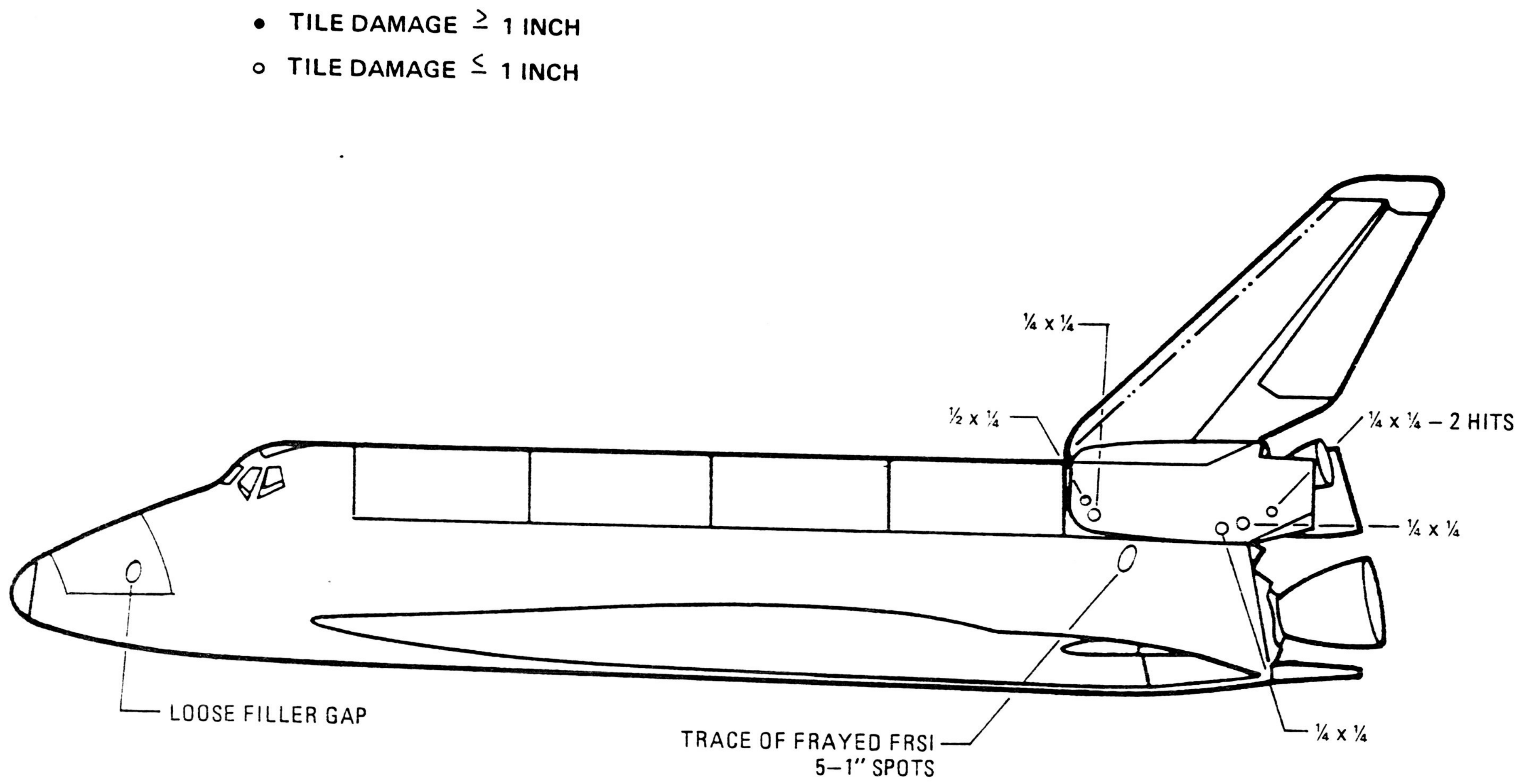


FIGURE 21. Orbiter Left Side

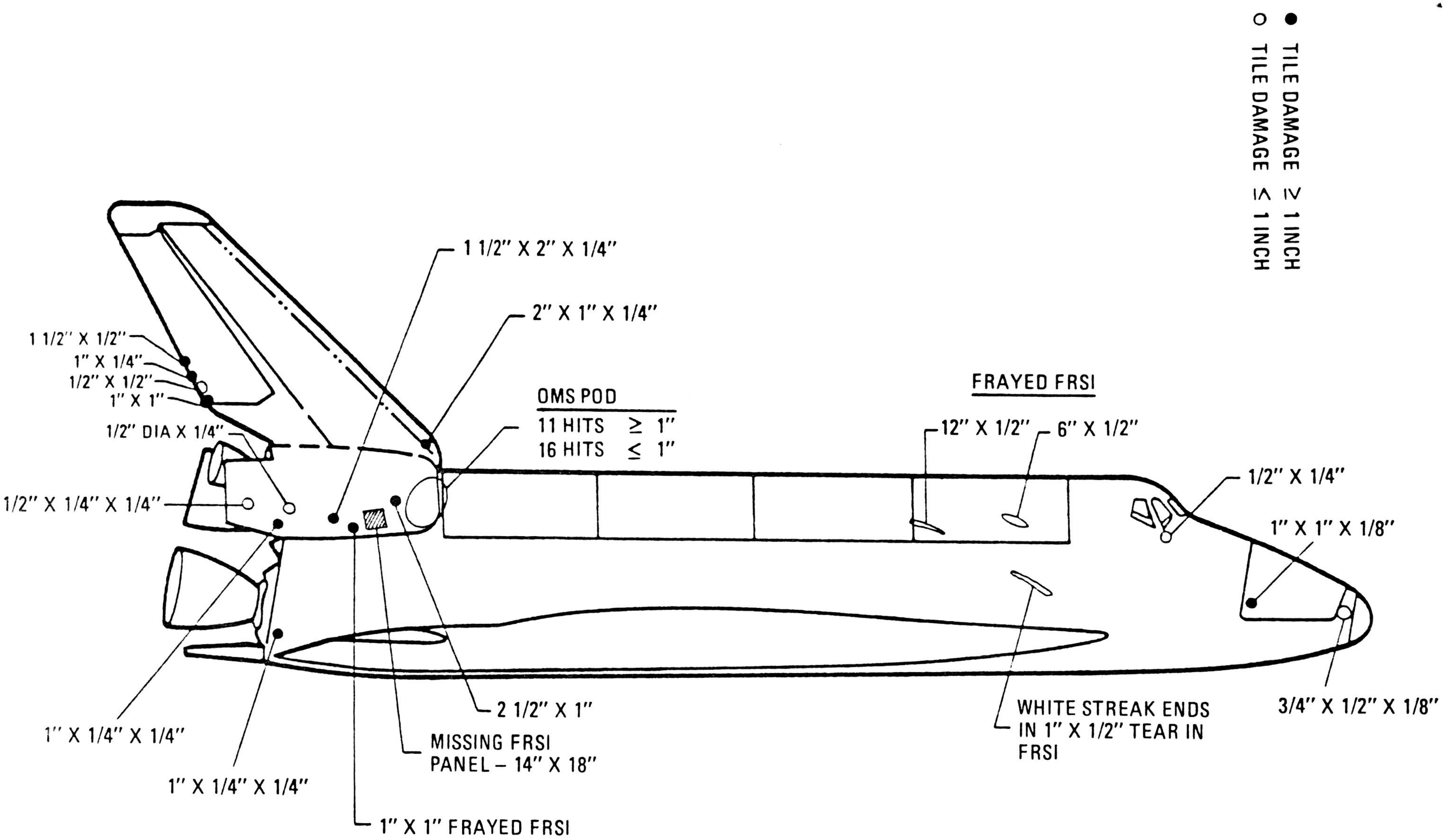


FIGURE 22. Orbiter Right Side

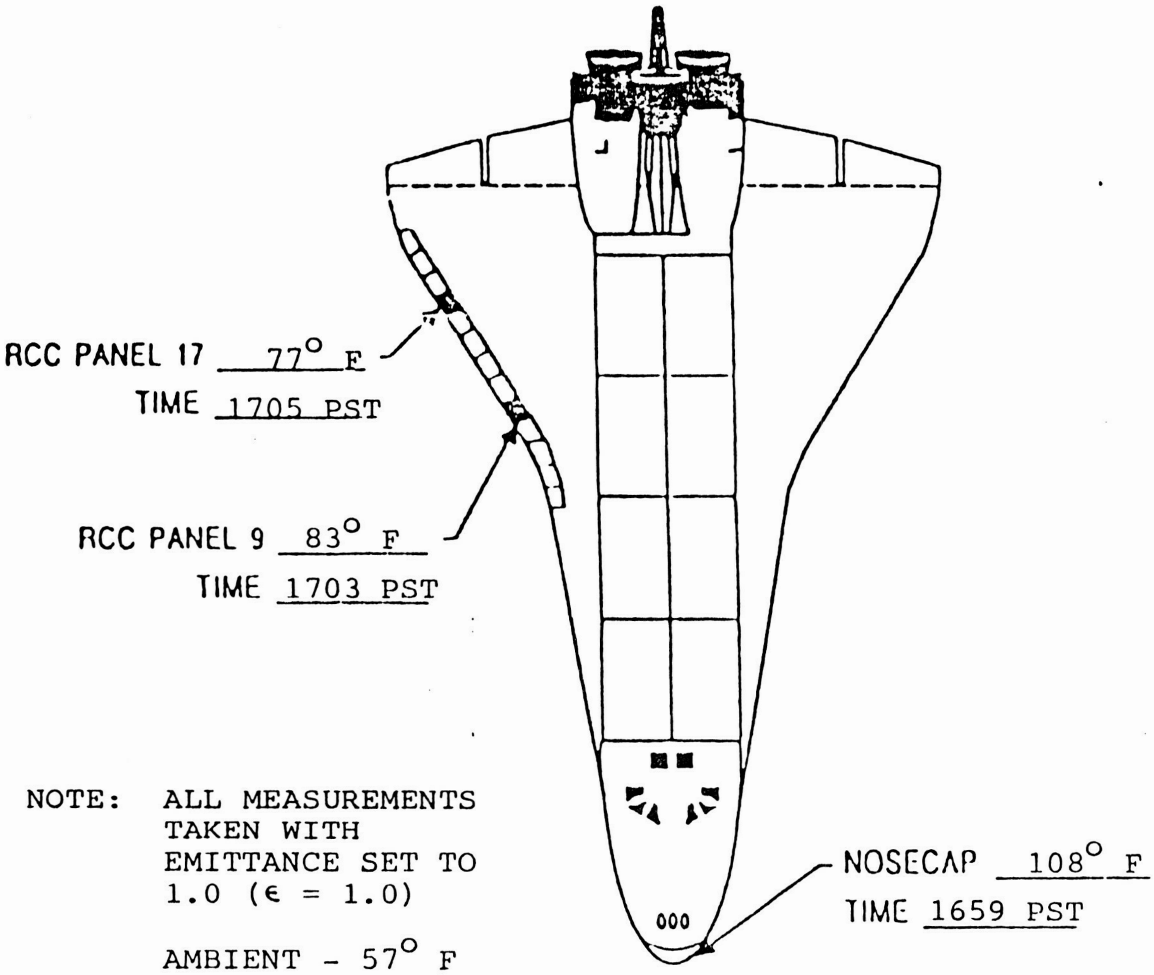
earlier revision of the job card, which omitted the washers, had thicker retaining rings, and provided fasteners with a shorter grip length than was called out in the current drawing. A Corrective Action Assistance Request has been initiated to resolve this problem.

The tires, wheels, and brakes were in good condition and were not a debris contributor. No tire or tile damage resulted from loose runway objects.

An infrared imaging system similar to the KSC Shuttle Thermal Imagers (STI) was used to record the thermal signature of the Orbiter and estimate the kinetic surface temperatures of several areas. During the landing and rollout, the scanner was equipped with a 10x telescope to permit closer inspection of the vehicle. Upon wheel stop, the scanner was moved to the 1250 foot convoy fall back position. Here, data collection continued with the 10x lens until clearance was given to move the scanner up to the orbiter (approximately 1 1/2 hours after wheel stop). The RCC temperature values presented in Figure 23 were obtained at the times noted after access was granted. All readings were obtained by positioning the imager perpendicular to the surface of interest and averaging the values over a small surface for statistical validity. The recorded temperatures were greatly influenced by the low ambient temperature (57 degrees F), time of day (after sundown when solar heating does not occur), and strong winds (increased convective cooling), which caused rapid cooling of the RCC nosecap and leading edge panels.

Total hits and hits greater than 1-inch were higher on this flight than any prior mission as shown in the following comparison chart (Figures 24, 25). The damage sites are typical of both shallow hits from low density material and deep gouges from higher density material. The high concentration of damage on the Orbiter right side lower surface outboard of a line from the bipod attachment to the ET-Orbiter LO2 umbilical suggests External Tank areas, such as the nosecone, LO2 tank, LO2 PAL ramp, and RH SRB forward assembly as suspect debris sources. The recovered SRBs revealed very little loss of material, though it should be noted the SRB nosecones were not recovered and could not be visually inspected. No damage sites could be attributed to EAFB runway debris sources.

An Orbiter TPS Damage Review Team was formed to investigate the cause of the tile damage and submit corrective actions to the NSTS program. The first priority of the team was to determine the origin of the tile-damaging debris. After OV-104 was returned to KSC, approximately 140 damaged tiles were removed. Foreign material, embedded in the damaged tiles, was submitted to the laboratory for analysis. Sixteen of 38 tile samples contained MSA-1 and/or Hypalon paint. Five of these 16 samples were physically located near the area of the missing tile



NOTE: ALL MEASUREMENTS TAKEN WITH EMITTANCE SET TO 1.0 ($\epsilon = 1.0$)

AMBIENT - 57° F

FIGURE 23. Post Landing Temperature Measurements

FIGURE 24. STS-27R DEBRIS DAMAGE ASSESSMENT SUMMARY

	Hits > or = 1"	Total Hits
Lower Surface	272	644
Upper Surface	5	21
Right Side	2	4
Left Side	0	0
Right OMS Pod	19	32
Left OMS Pod	0	6
TOTALS	298	707

COMPARISON TABLE

STS-6	36	120
STS-7	48	253
STS-8	7	56
STS-9 (41-A)	14	58
STS-11 (41-B)	34	63
STS-13 (41-C)	8	36
STS-14 (41-D)	30	111
STS-17 (41-G)	36	154
STS-19 (51-A)	20	87
STS-20 (51-C)	28	81
STS-23 (51-D)	46	152
STS-24 (51-B)	63	140
STS-25 (51-G)	144	315
STS-26 (51-F)	226	553
STS-27 (51-I)	33	141
STS-28 (51-J)	17	111
STS-30 (61-A)	34	183
STS-31 (61-B)	55	257
STS-32 (61-C)	39	193
STS-26R	55	411
STS-27R	298	707

ORBITER TILE DAMAGE DATA

LAUNCH SUMMARY (LW-1 AND SUBS)

STS	LW	LAUNCH	T-SURF	TANKINGS	ORB	LANDING	NUMBER OF DEBRIS HITS ENTIRE VEHICLE TOT	NUMBER OF DEBRIS HITS ENTIRE VEHICLE >1 IN	LOWER SURFACE TOT	LOWER SURFACE >1 IN
6	1	APR 83	48° F	3 (2 FRF)	099-1	EAFB-22	120	36	80	15
8	2	AUG 83	55° F	1	099-3	EAFB-22	56	7	29	3
9	4	NOV 83	65° F	2	102-3	EAFB-17	58	14	49	9
11	3	FEB 84	31° F	1	099-4	KSC-15	63	34	19	11
13	5	APR 84	38° F	1	099-5	EAFB-17	36	8	27	5
14	6	AUG 84	53° F	4 (1 FRF)	103-1	EAFB-17	111	30	44	10
17	8	OCT 84	53° F	1	099-6	KSC-33	154	36	69	25
19	9	NOV 84	51° F	2	103-2	KSC-15	87	20	66	14
20	7	JAN 85	37° F	1	103-3	KSC-15	81	28	67	24
23	11	APR 85	51° F	1	103-4	KSC-33	152	46	111	43
24	10	APR 85	63° F	1	099-7	EAFB-17	140	63	110	45
25	13	JUN 85	61° F	1	103-5	EAFB-23	315	144	231	109
26	12	JUL 85	62° F	2	099-8	EAFB-23	553	226	482	179
27	14	AUG 85	64° F	3	103-6	EAFB-23	141	33	96	21
28	18	OCT 85	67° F	2 (1 FRF)	104-1	EAFB-23	111	17	66	7
30	17	OCT 85	60° F	1	099-9	EAFB-17	183	34	129	24
31	15	NOV 85	49° F	1	104-2	EAFB-22	257	55	177	37
32	23	JAN 86	33° F	5	102-4	EAFB-22	193	39	134	20
33	19	JAN 86	14° F	2	099-0	NA				
26R	21	SEP 88	63° F	5 (2 FRF)	103-7	EAFB-17	411	55	342	47
27R	16	DEC 88	34°F	2	104-3	EAFB-17	707	298	644	272

FIGURE 25.

(Figure 26). In addition, material found on an RCC panel of the RH wing exhibited a Hypalon paint signature in laboratory testing. Since the damage was concentrated on the right side of the Orbiter and the RH SRB FWD skirt had lost virtually no TPS, the investigation concentrated on the historical records of the RH SRB nosecap. Several processing variations were discovered that may have caused the nosecap to lose MSA-1/Hypalon topcoat in flight.

Several pieces of SRB joint cork closeout material were found missing during the retrieval inspection, though most of these locations were too far aft on the vehicle to have caused the severe tile damage (Figure 27).

While OV-104 was being inspected in the OPF, a TPS fragment was found in a cavity where the RH OMS pod joins the fuselage. Lab tests determined this sample was PDL foam with FRL topcoat, a combination found only in repairs to the ET nose cone GOX seal footprint area.

A full length axial repair had been made to the LO2 tank PAL ramp on ET-23. This type of repair, with a longitudinal isochem bondline, resulted in a unique flight configuration which had not been validated by plug pull tests prior to flight. Although a post mission lab test was initiated to demonstrate the required ultimate safety factor of the TPS/substrate bondline, the test did not address any possible TPS cohesive type of failure.

Analyses were conducted to determine the probability of suspected debris from the SRB (nose cap) and ET (nosecone area and LO2 PAL ramp) impacting the Orbiter tiles at the locations where the damage occurred. The analyses also attempted to confirm that the debris maintained structural integrity while crossing the Orbiter nose shock wave and retained sufficient impact energy to cause the damage. The methods utilized in the analyses were: 1) debris transport trajectory parametric analysis using STS aerodynamic computational fluid dynamic codes, 2) wind tunnel oil flow correlations to tile damage location, and 3) energy of debris as a function of Orbiter damage location and flight attitude.

The results of the analyses (Ref. Orbiter TPS Damage Review Team Report) show that, based on debris energy versus tile damage energy thresholds, SRB nose cap material can damage Orbiter tiles between Mach 0.4 and 3.75. Similarly, ET TPS is likely to cause tile damage between Mach 0.4 and 2.5. The wind tunnel oil flow test results correlate well with the Orbiter tile damage pattern between Mach 1.0 to 2.5. The Orbiter inboard elevons, which are moved upward out of the direct aerodynamic flow field by design at Mach 2.5, sustained no TPS damage. The analyses therefore concluded that the event causing the severe tile damage occurred after Mach 2.5 near T+85

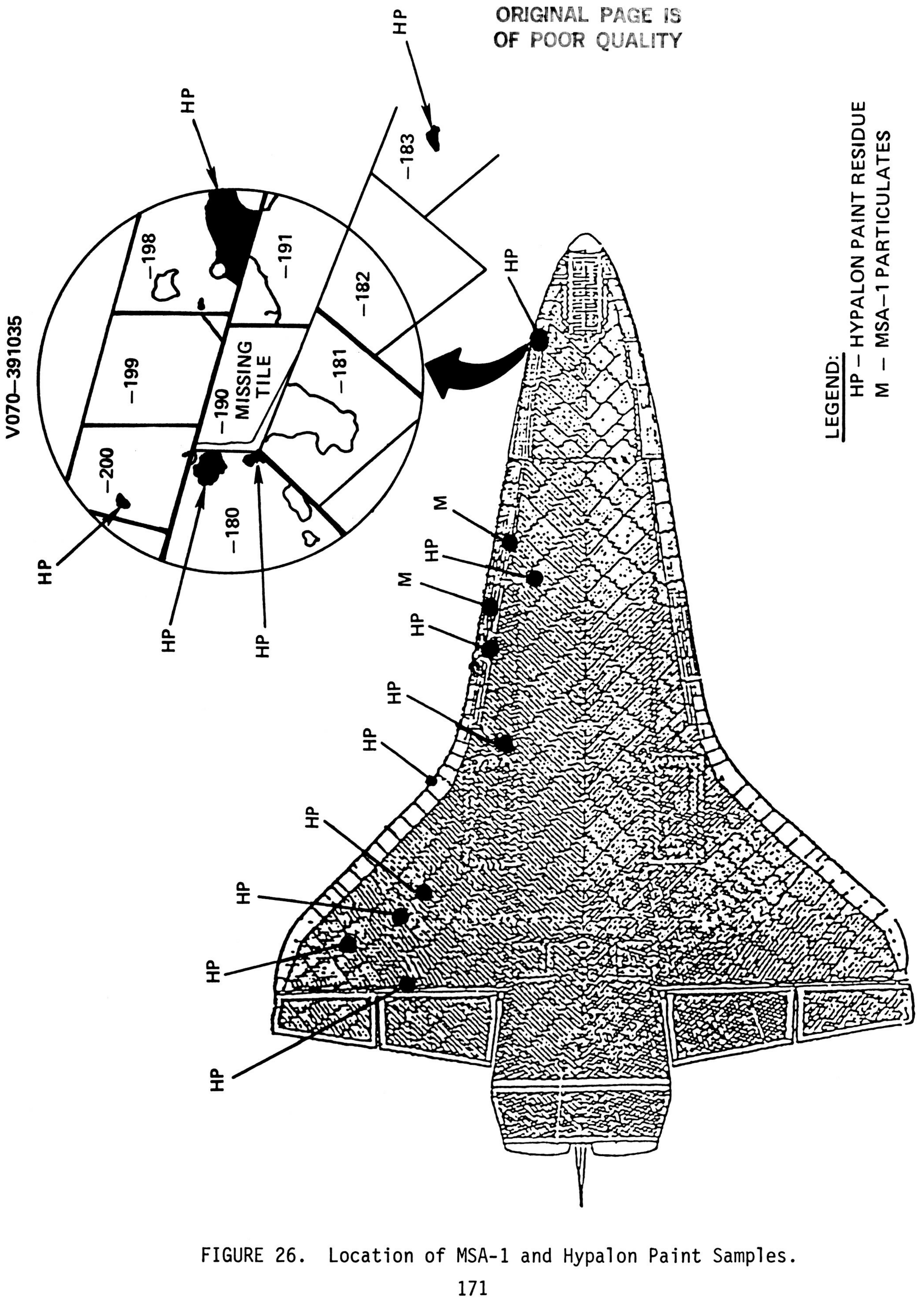
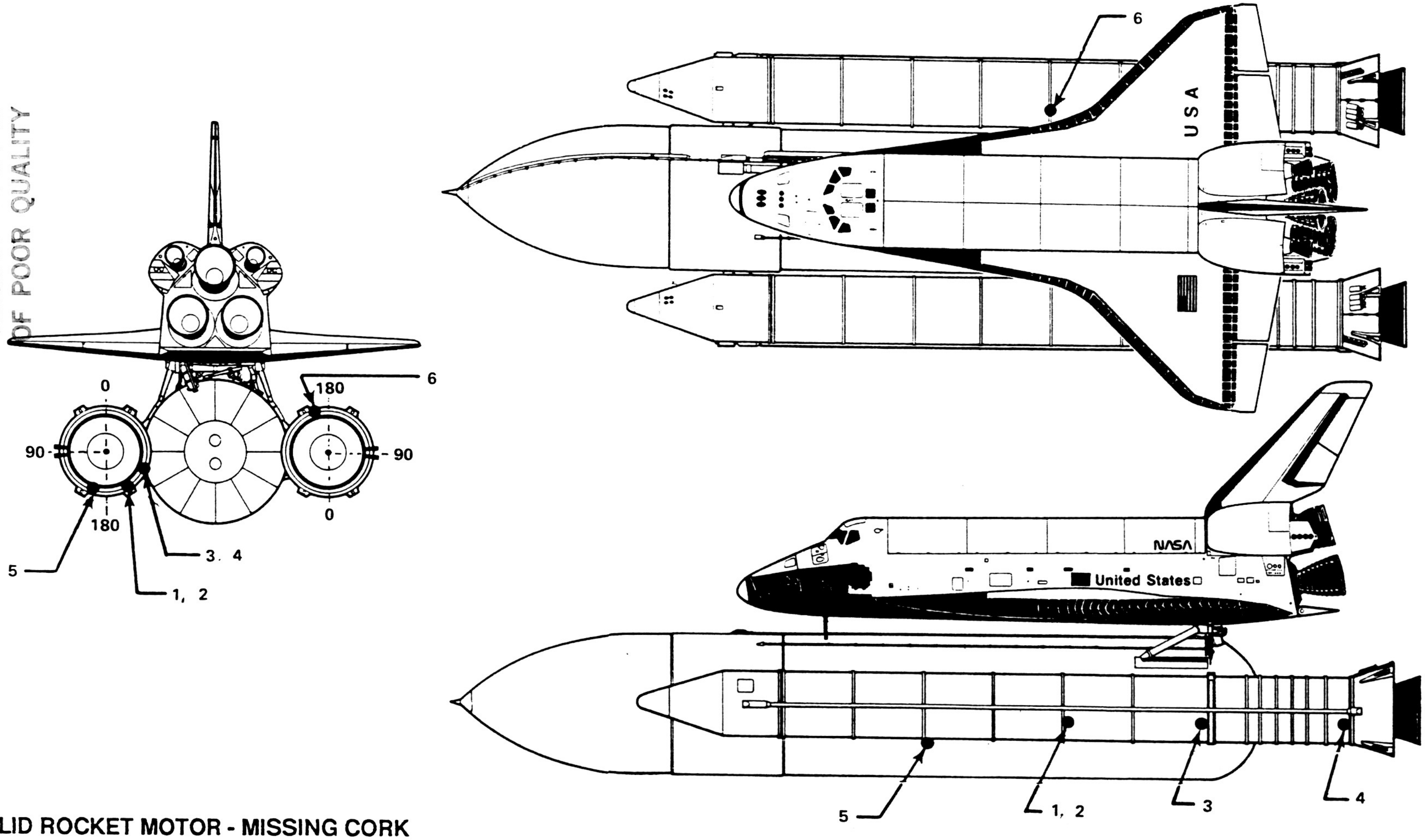


FIGURE 26. Location of MSA-1 and Hypalon Paint Samples.

SRM MISSING CORK



SOLID ROCKET MOTOR - MISSING CORK

o LEFT MOTOR -

* 1 CAP CORK - CENTER JOINT	- 244° POSITION	- 2.5" X 2"
* 2 CAP CORK - CENTER JOINT	- 248° POSITION	- 3" X 1.5"
* 3 CAP CORK - AFT JOINT	- 215° POSITION	- 2.5" X 5"
4 CAP CORK - AFT SEGMENT	- 218° POSITION	- 1" X 5"
5 CAP CORK - FWD JOINT	- 170° POSITION	- .75" X .75"

o RIGHT MOTOR -

6 ONE PIECE JOINT PROTECTION CORK-CENTER JOINT - 185° LOCATION - 3.5" X 3.5"

* IMPACTS FROM NOZZLE SEVERENCE

FIGURE 27. SRM Missing Cork

seconds MET. SRB and ET TPS materials do have sufficient energy and transport mechanism to reach Orbiter tiles and cause severe damage.

The Orbiter TPS Damage Review Team concluded that the most probable cause of the severe tile damage on STS-27R was the ablative insulating material on the RH SRB nose cap dislodging and striking Orbiter tiles near T+85 seconds MET.

Further, it is highly probable that debris from other sources, such as ET TPS and SRB joint cork closeouts, caused additional minor tile damage. At launch, the ET ice condition was well within the launch data base for ice formation. Ice may have caused minor tile damage, but was not a major contributor.

Changes to the STS-29R flight hardware to eliminate possible debris sources include additional plug pull tests on the SRB nose caps, frustums, and forward skirts, and ET TPS. The tests confirmed the TPS adhesive/cohesive bond strengths met or exceeded acceptable specifications. Vent holes have been drilled in the SRM field joint cork closeouts to relieve entrapped air pockets.

Improvements in airborne and ground-based photographic coverage are planned. A motion picture camera will be mounted in the crew cabin to record debris particles passing by the forward facing windows. The flight crew is evaluating a request to maneuver the Orbiter and photograph the External Tank as soon as possible after separation. This documentation is expected to reveal the post-ascent condition of the ET.

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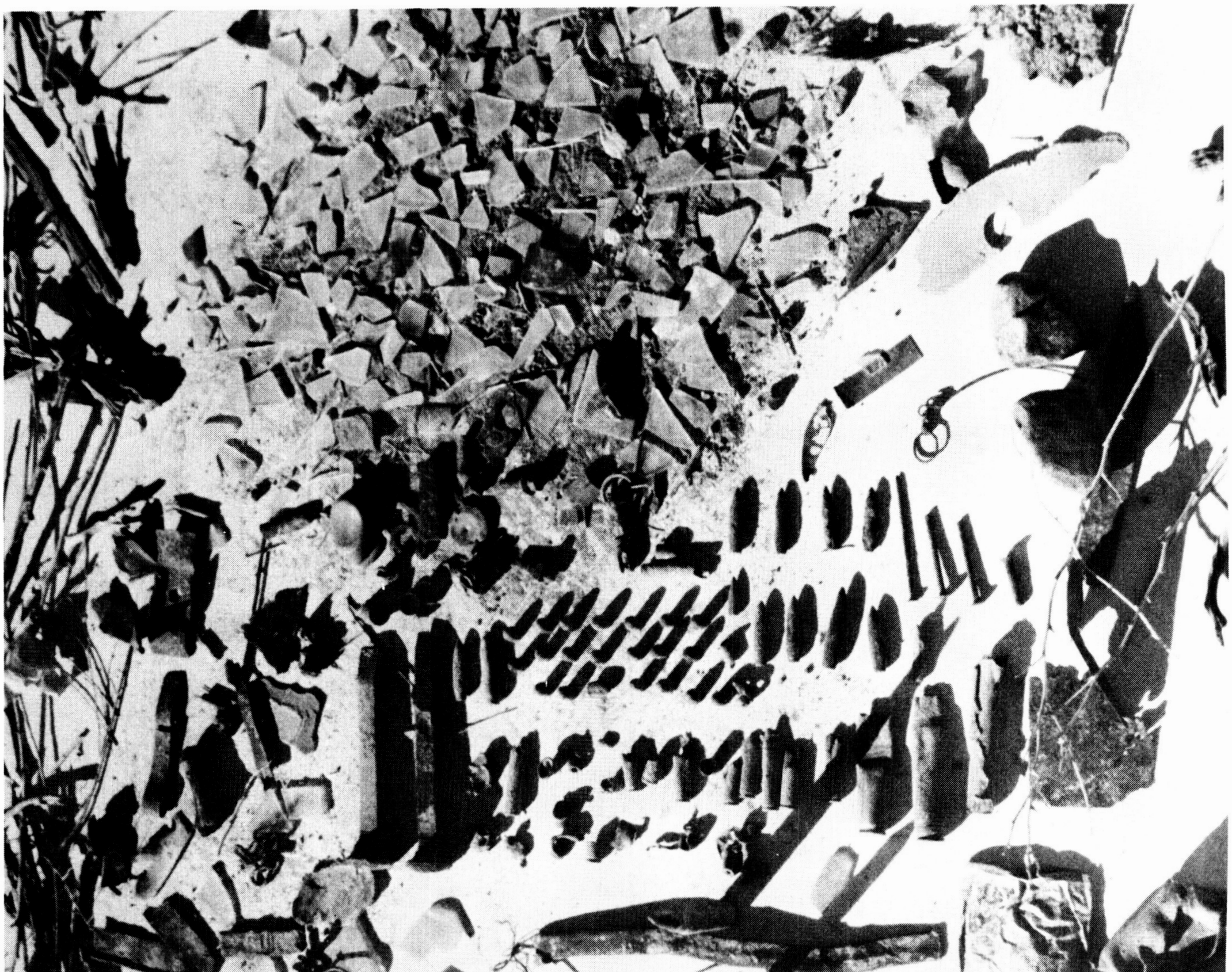

DEBRIS COLLECTED DURING PRE-LANDING RUNWAY INSPECTION

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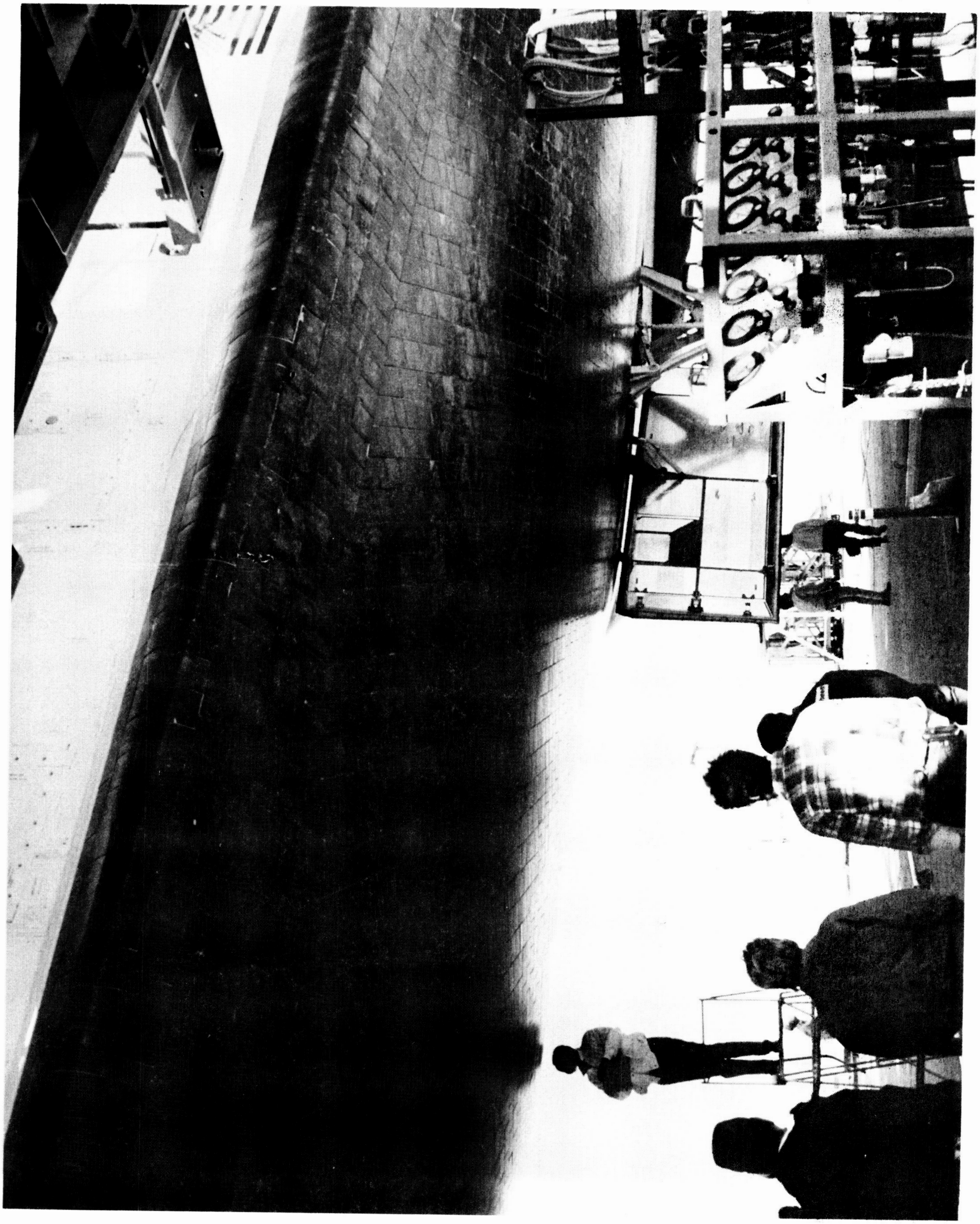
FRAGMENTS OF OUTBOARD FORWARD CORNER TILE FROM RH MLG DOOR
FOUND ON RUNWAY APPROACH THRESHOLD AFTER LANDING



MINIMAL DAMAGE ON LH FORWARD LOWER FUSELAGE AND CHINE AREA.

MINIMAL TPS DAMAGE ON LH WING AND ELEVON LOWER SURFACES

TYPICAL TILE 'DINGS' ON BASE HEAT SHIELD

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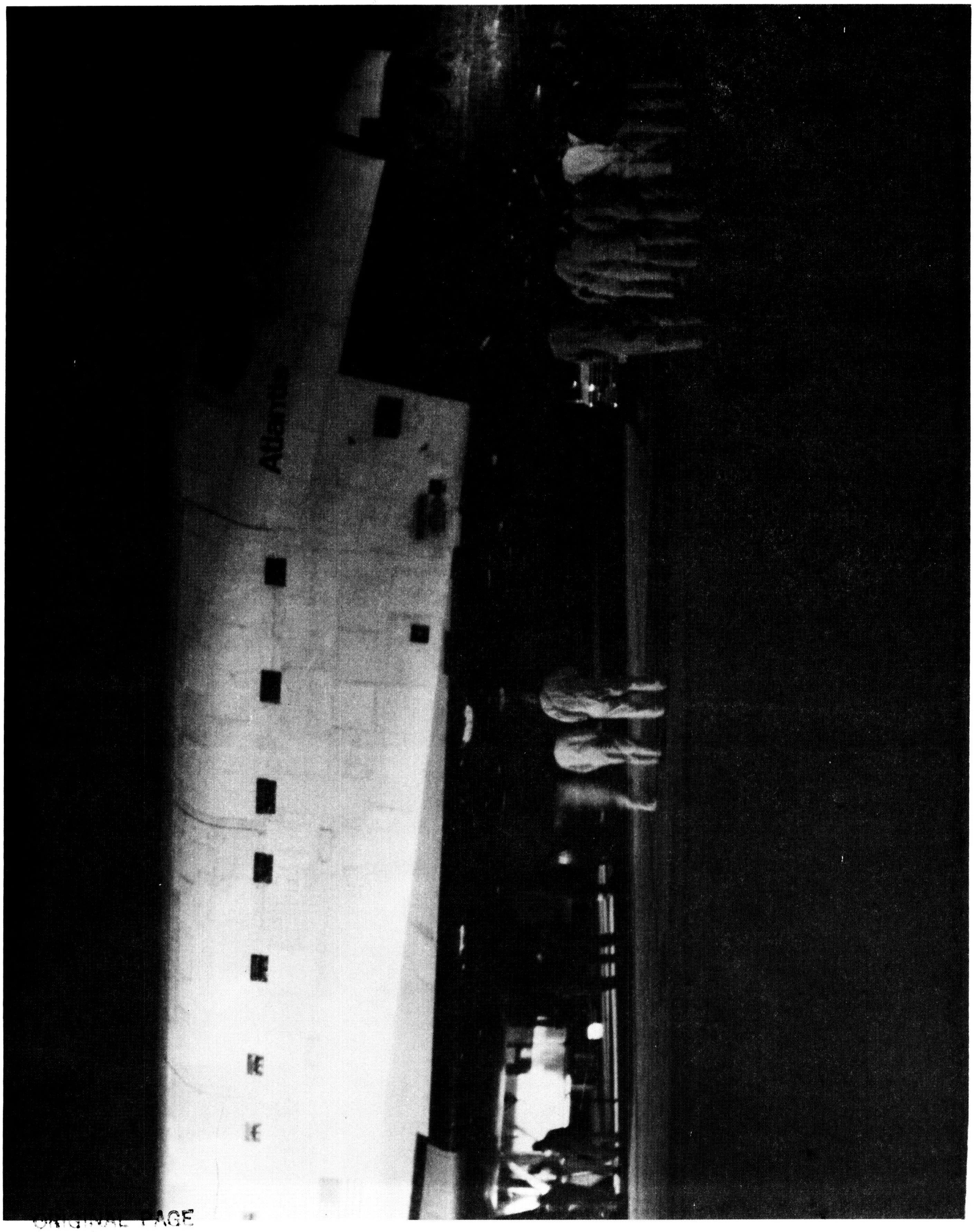

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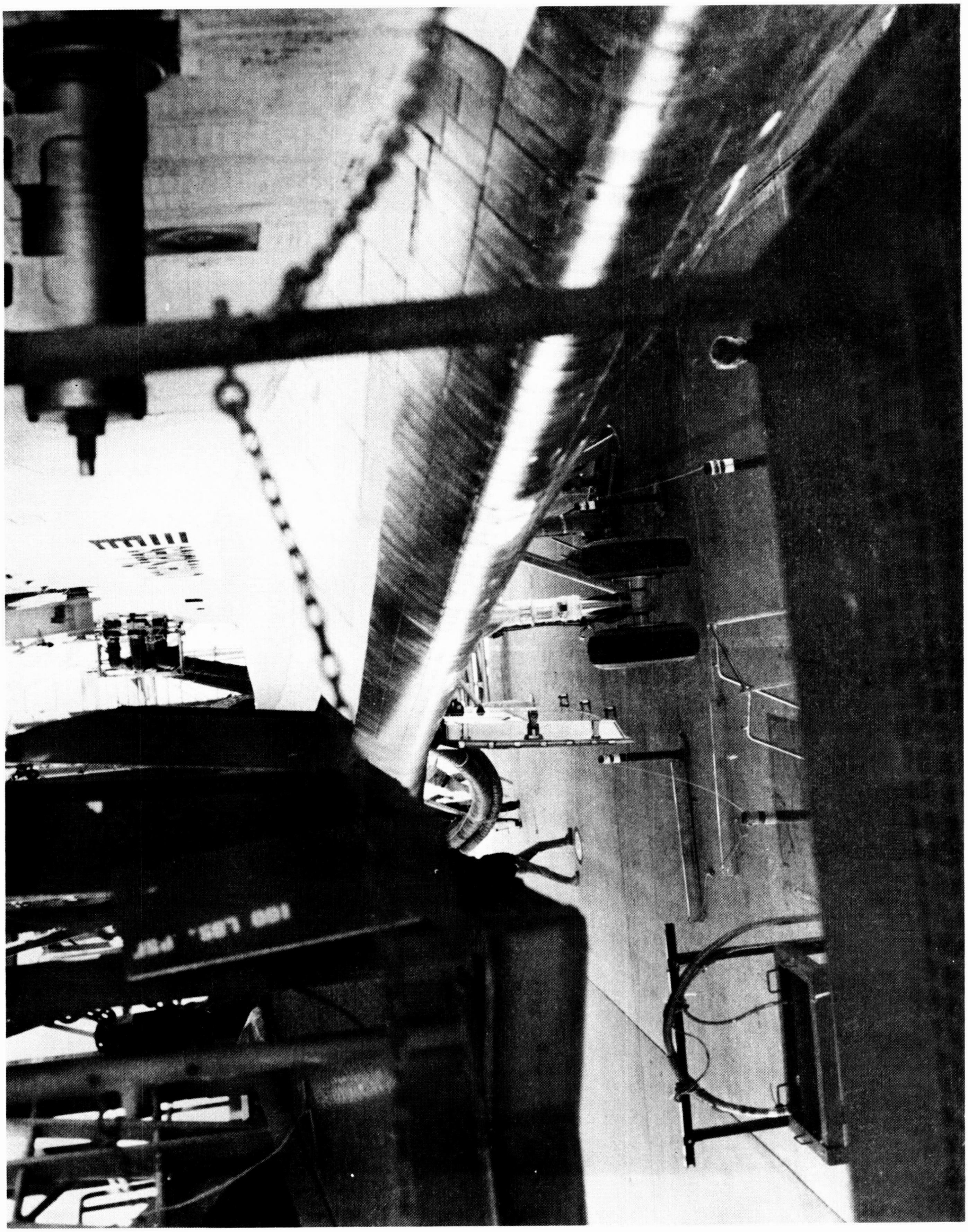
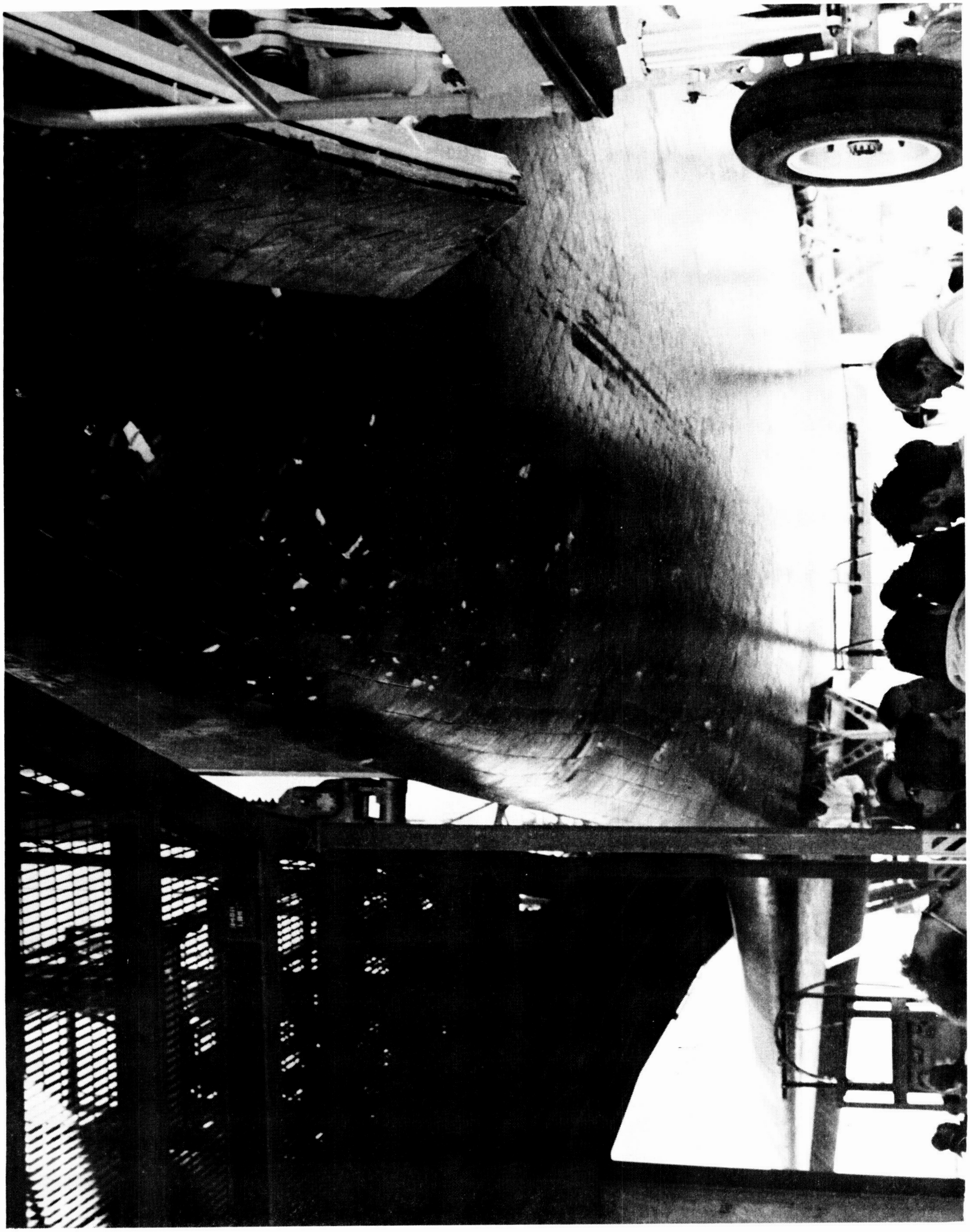
LAKEBED INSPECTION OF ORBITER. SEVERAL AREAS OF WIDE SHALLOW TILE PENETRATIONS ON RH CHINE ARE VISIBLE

TILE DAMAGE CONCENTRATED ON RH CHINE AND WING LOWER SURFACE



MINIMAL TILE DAMAGE ON RH CHINE AND WING UPPER SURFACE



DEBRIS DAMAGE CONCENTRATION AROUND MISSING TILE ON RH FUSELAGE FORWARD LOWER SURFACE

MISSING TILE WAS LOCATED NEAR NOSE LANDING GEAR DOOR

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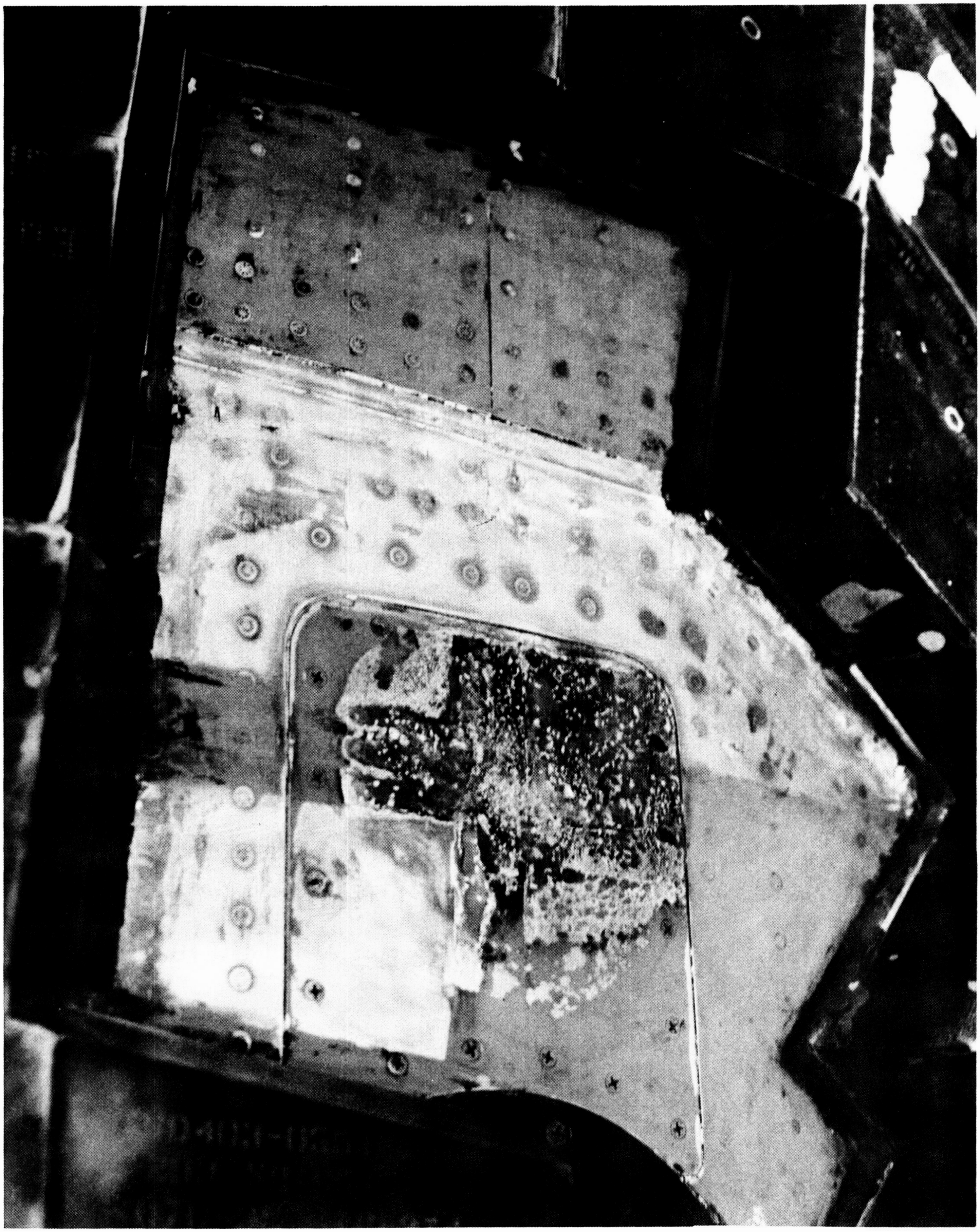
CHARRED SIP AND METAL SUBSTRATE IN CAVITY OF MISSING TILE SHOW EFFECTS OF REENTRY HEATING



DAMAGED TILES REMOVED PRIOR TO FERRY FLIGHT. SCOPE OF REENTRY HEATING DAMAGE IS VISIBLE ON L-BAND ANTENNA DOOR

WIDE, SHALLOW TILE COATING DAMAGE AND LONG, DEEP TILE GOUGES ON RH CHINE AND FORWARD LOWER FUSELAGE

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LARGE DAMAGE SITE INVOLVING 5 TILES ON RH CHINE HAS BEEN ERODED AND REGLAZED DUE TO REENTRY HEATING.

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COMBINATION OF SHALLOW AND DEEP TILE PENETRATIONS ON RH LOWER MID-FUSELAGE

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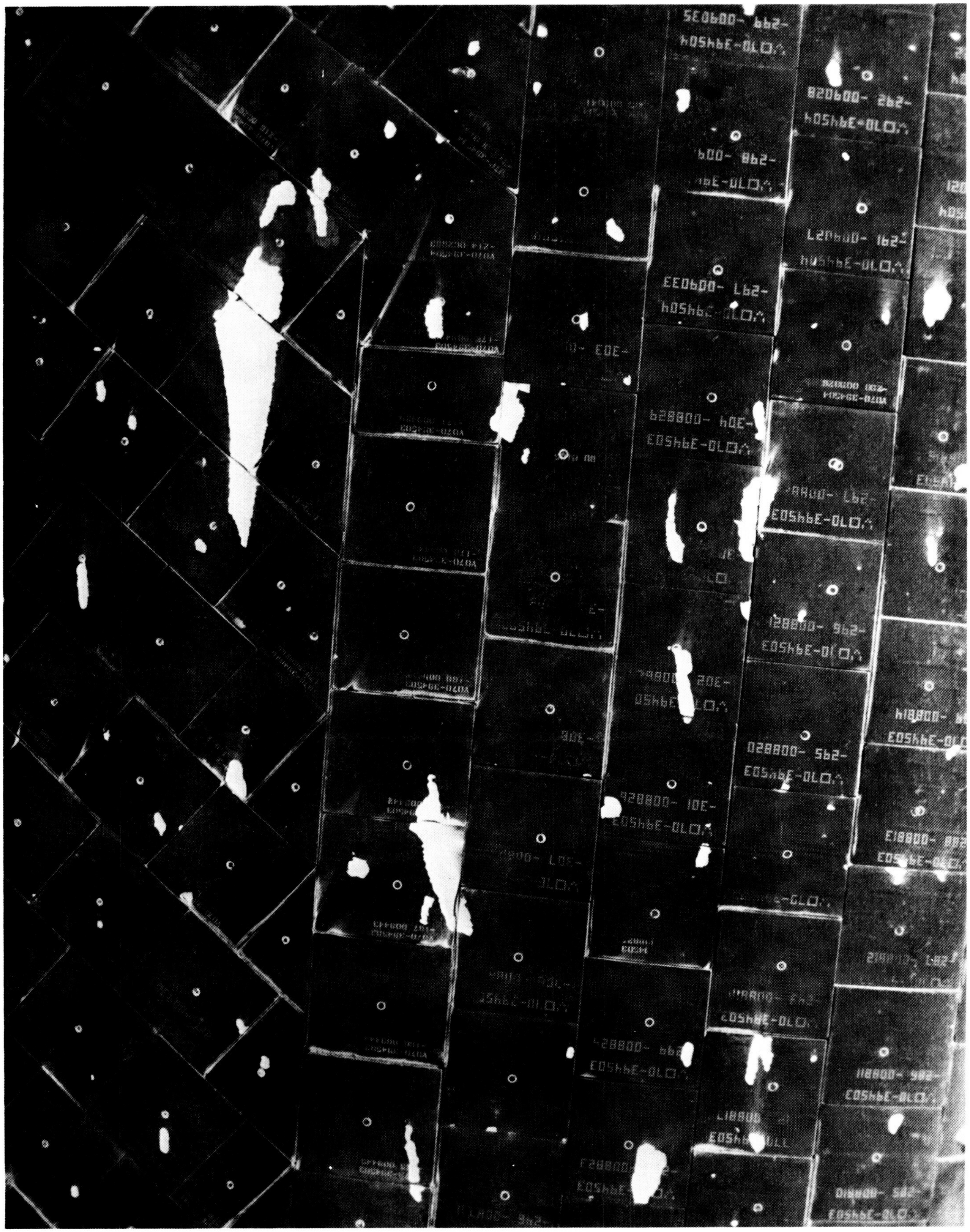

STRAIGHT LINE PATTERN OF DEBRIS DAMAGE
TO TILES ON RH LOWER MID-FUSELAGE

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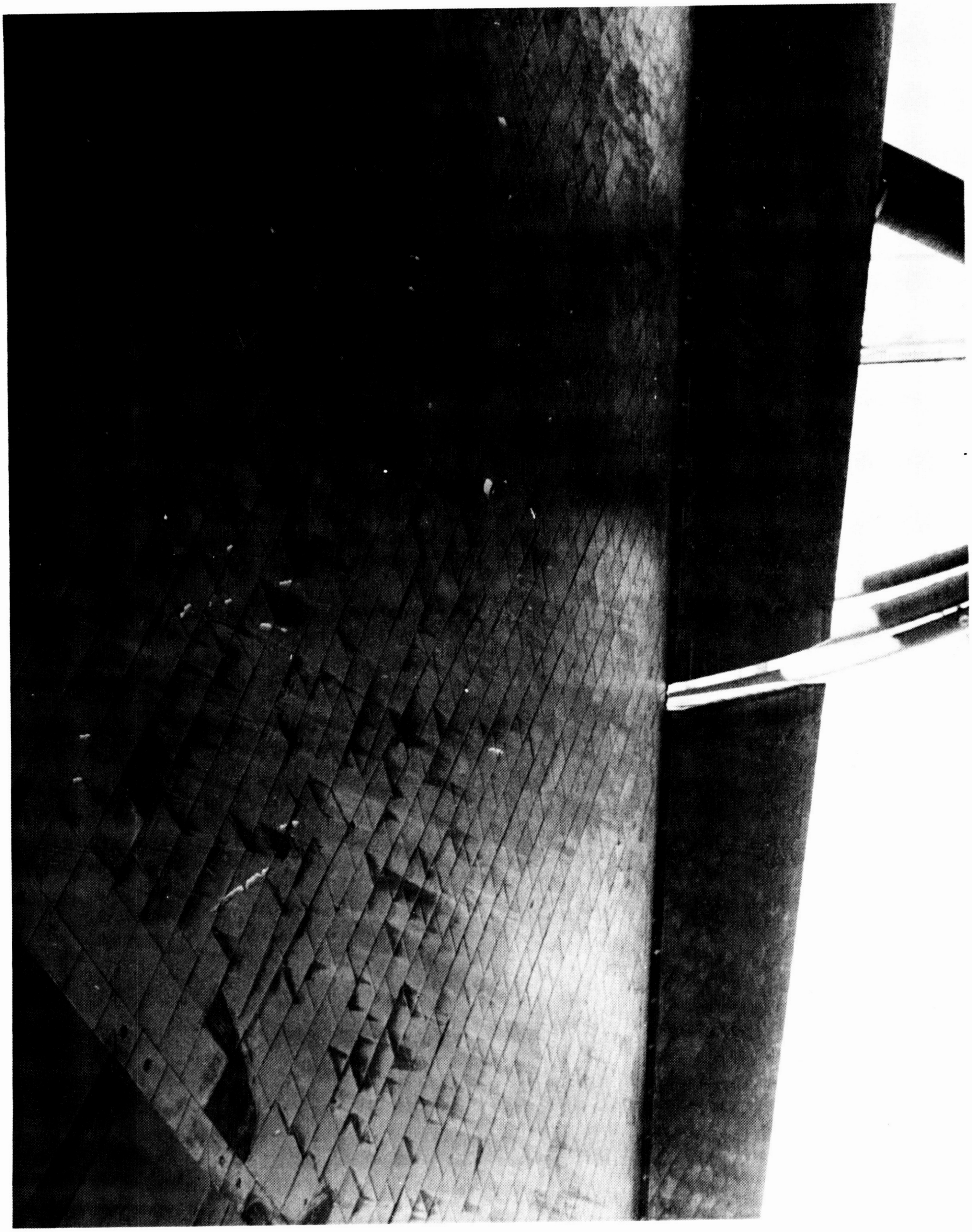
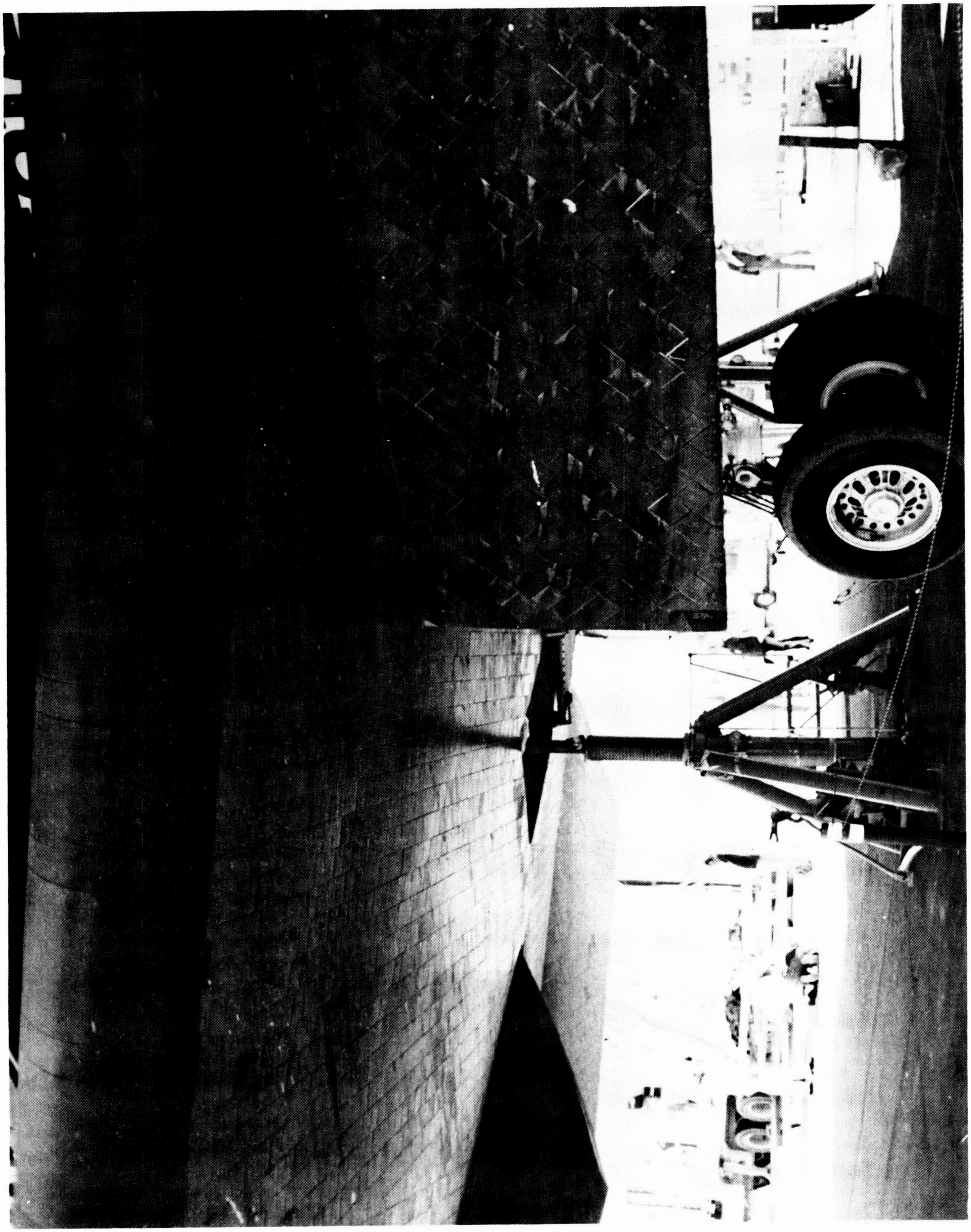


DAMAGE STREAKS ON RH WING LOWER SURFACE.
NO DAMAGE TO RH ELEVONS.

C-2



STREAKS ON RH WING RCC LEADING EDGE. DAMAGE TO RH WING LOWER SURFACE AND RH MLG DOOR.

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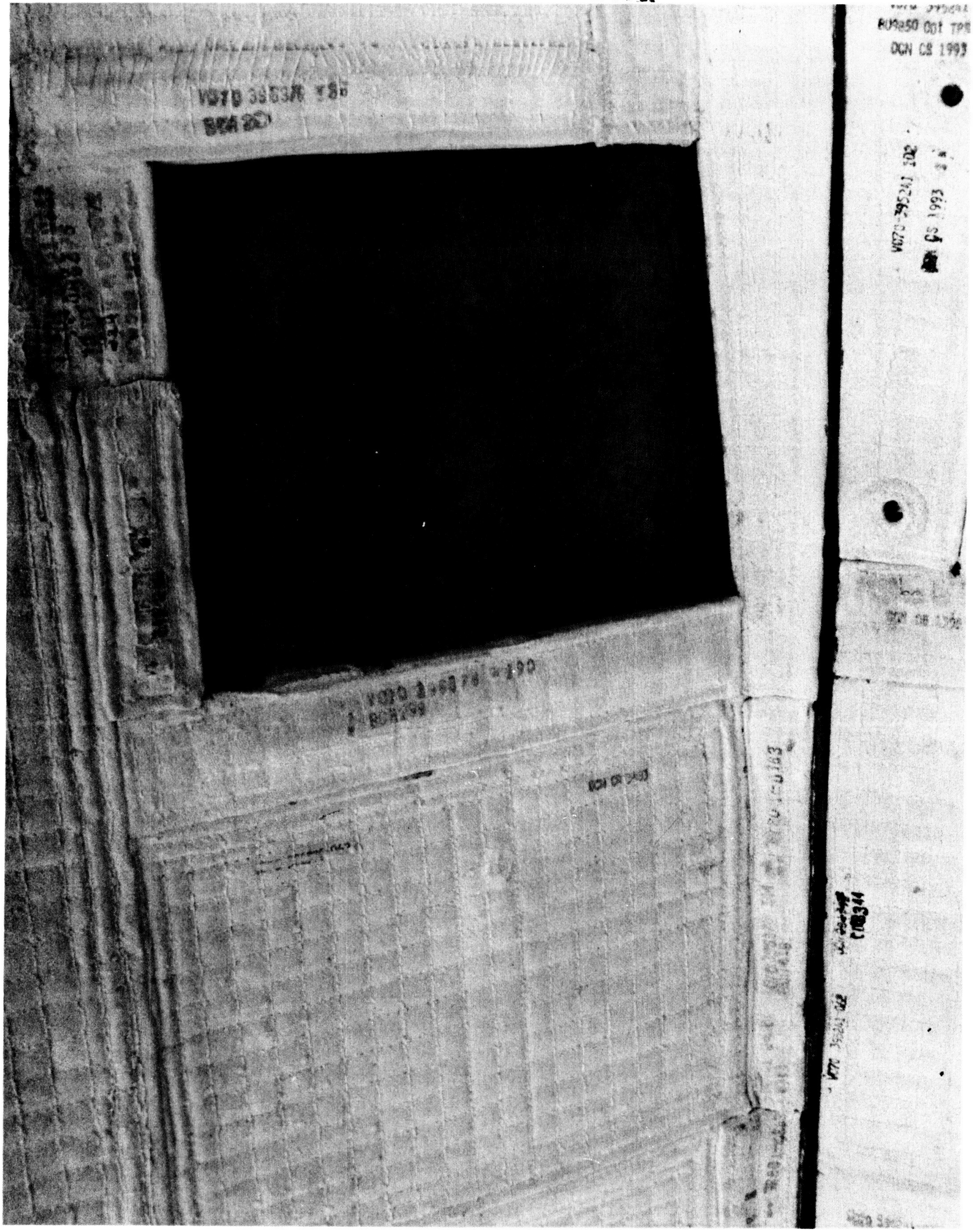

RH OMS POD CARRIER PANEL LOST DURING ASCENT. DOOR OVER ATTACH POINT #9 SHOWS NO APPARENT DAMAGE FROM ASCENT AEROHEATING.

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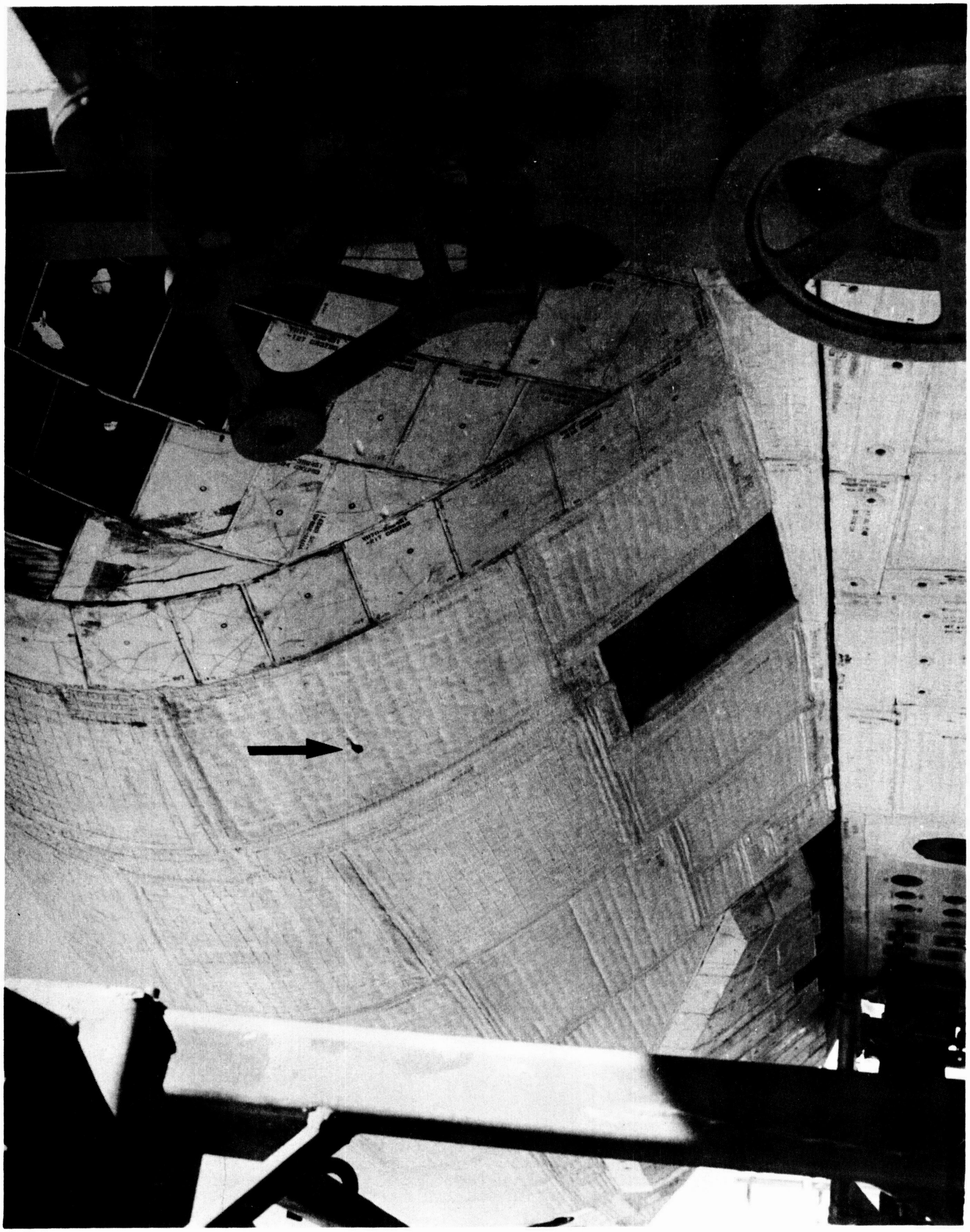
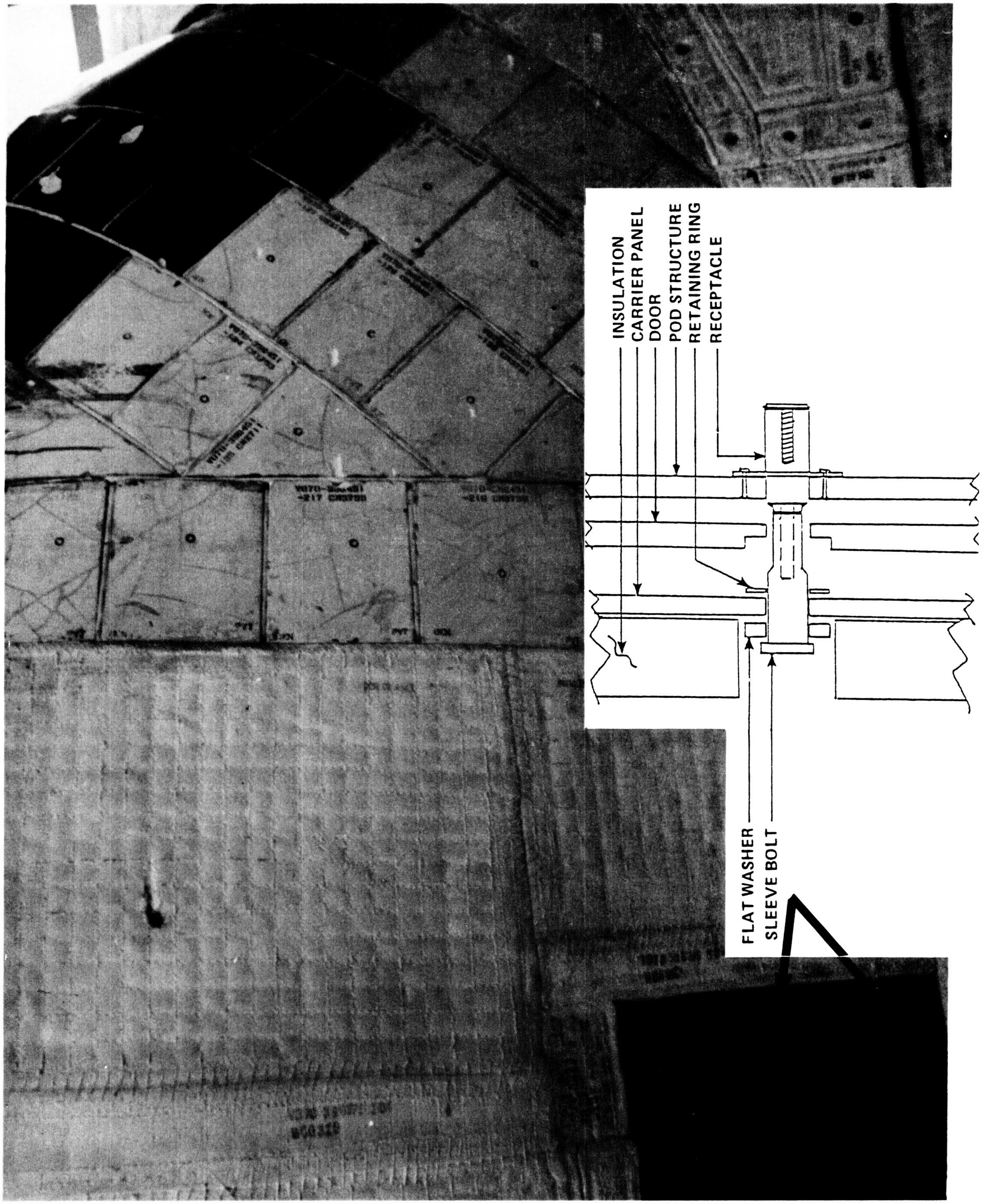


LOCATION OF MISSING RH OMS POD CARRIER PANEL, TILE DAMAGE BY ASCENT DEBRIS, AND DEEP AFRSI PENETRATION.



DETAIL OF IMPROPERLY INSTALLED PANEL BOLTS. TILES WERE DAMAGED BY DEBRIS. DEEP DEBRIS PENETRATION OF AFRSI IN UPPER LEFT AREA.

National Aeronautics and Space Administration

Report Documentation Page

1. Report No. TM 102144	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Ice/Frost/Debris Assessment for Space Shuttle Mission STS-27R		5. Report Date February 1989
		6. Performing Organization Code
7. Author(s) Charles G. Stevenson Gregory N. Katnik Scott A. Higginbotham		8. Performing Organization Report No.
		10. Work Unit No.
9. Performing Organization Name and Address NASA ET Mechanical Systems Division Mail Code: TV-MSD-22 Kennedy Space Center, Florida 32899		11. Contract or Grant No.
		13. Type of Report and Period Covered
12. Sponsoring Agency Name and Address		14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

An Ice/Frost/Debris assessment was conducted for Space Shuttle Mission STS-27R. Debris inspections of the flight elements and launch pad are performed before and after launch. Ice/frost conditions are assessed by the use of computer programs, nomographs, and infrared scanner data during cryogenic loading of the vehicle followed by an on-pad visual inspection. High speed photography is viewed after launch to identify ice/debris sources and evaluate potential vehicle damage. This report documents the Ice/Frost/Debris conditions of Mission STS-27R and their effect on the Space Shuttle Program.

17. Key Words (Suggested by Author(s)) STS-27R Ice Frost Debris		18. Distribution Statement Publicly Available Unclassified - Unlimited	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of pages	22. Price

NASA FORM 1626 OCT 86